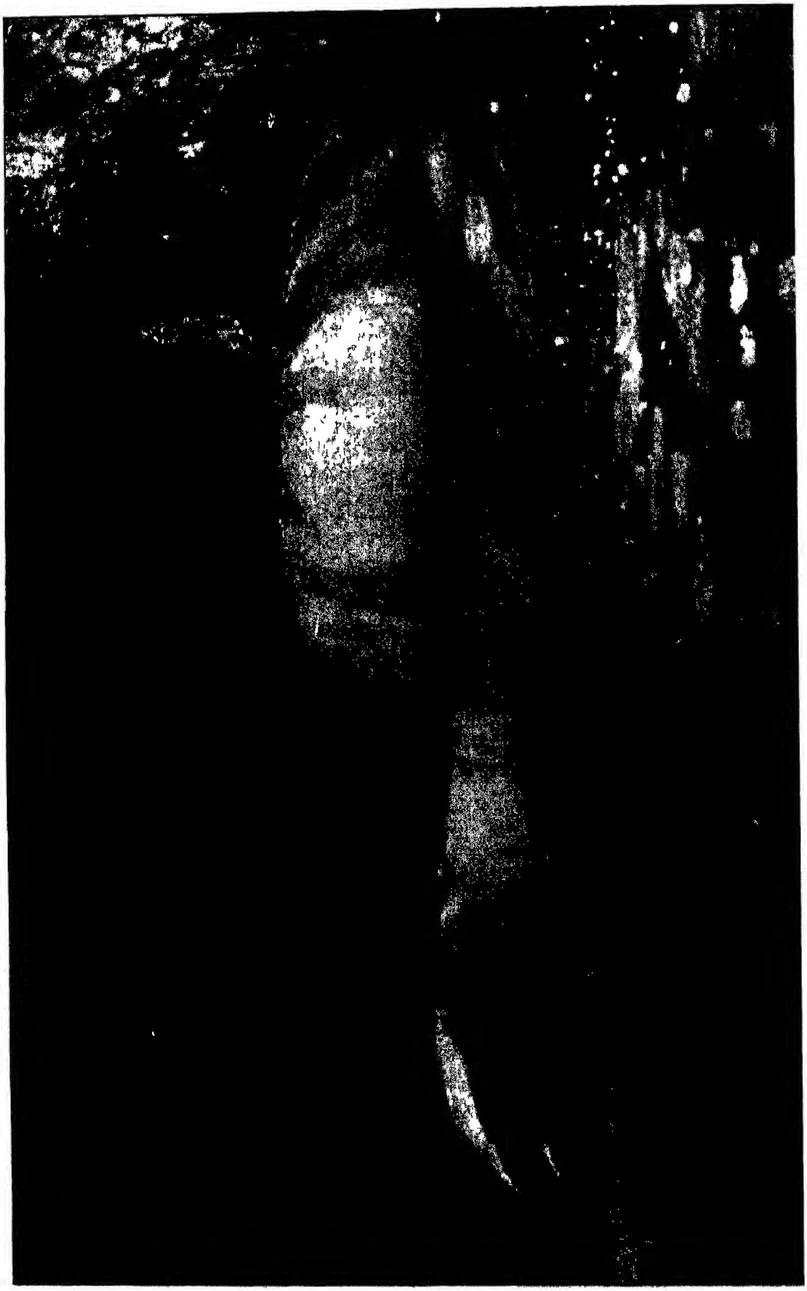
GLACIERES

OR

FREEZING CAVERNS



GLACIERES

OR

FREEZING CAVERNS

BY

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PHILADELPHIA
ALLEN, LANE & SCOTT
1900

THIS BOOK IS

AFFECTIONATELY DEDICATED TO

MY MOTHER,

WHOSE DEEP INTEREST IN

MY WORK HAS

HELPED ME GREATLY.

PRELIMINARY NOTE.

MANY kind friends have given me information about glacières or assistance in my work. I am especially indebted to Mr. Robert Butler, of San José, Cal.; Mr. F. H. Cushing, of Washington, D. C.; Professor Charles E. Fay, of Tufts College, Mass.; Professor Eberhard Fugger, of Salzburg, Austria; Mr. Alois F. Kovarik, of Decorah, Iowa; Monsieur E. A. Martel, of Paris, France; Mr. John Ritchie, Jr., of Boston, Mass.; Professor I. C. Russell, of Ann Arbor, Mich.; Miss H. Varena, of Wiesbaden, Germany; and Miss Mary Coxe, Mr. G. L. Farnum, Mr. J. E. Farnum, Mr. F. L. Garrison, Mr. W. C. Hall, Mr. E. I. H. Howell, Mrs. Horace Jayne, Mr. W. E. Meehan, Mr. C. J. Nicholson, Mr. G. B. Phillips, Mr. Bunford Samuel, Mr. W. W. Wagner, and Dr. W. H. Wahl, of Philadelphia. I wish to acknowledge also the help I have derived from the Bibliothèque Nationale and the library of the British Museum.

E. S. B.

PHILADELPHIA, February the 10th, 1900.

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EXPERIENCES IN GLACIÈRES.

SUBTERRANEAN ICE IN KING'S RAVINE.

Subterranean ice was brought to my notice by a mere accident, late in the month of September, 1877, while on a descent of King's Ravine, on Mount Adams, in the White Mountains of New Hampshire. We had just descended the rock wall of the mountain and had reached the head of the gorge, when my companion, Mr. Charles E. Lowe, the well-known Appalachian guide of Randolph, suddenly said to me, "Would you like a piece of ice? I can get you some presently." I answered, "Certainly," wondering where he would find any. When we got among the big boulders, which form so rough a path for the traveler at the bottom of the ravine, Mr. Lowe climbed down under one of the biggest, and presently reappeared with a good sized lump of ice. I was much impressed at finding ice at the end of the summer in this gorge, when for months past no ice or snow had been visible on the surrounding mountains. I noticed also the peculiar, flaky formation of the ice, and saw at once that it was something new to me,

and in fact it was a piece of what I have since learned to know as "prismatic ice."

GLACIÈRE NEAR BRISONS.

In the summer of the year 1880, I traveled through the Alps, with a friend from Philadelphia. On the 17th of September, we drove from Geneva to Bonneville. Thence we started on foot without a guide, and as a result got lost in the woods, from which we only extricated ourselves at nightfall. After retracing our steps to Bonneville, we were glad to find a man to show us the way we should have taken, and finally reached the little village of Brisons in France, where we slept. The next day we took a guide and made our way across the mountains to Annecy, at one spot going out of our direct route to see a place spoken of by the natives as a glacière. It was a little pit, and at the base of one side thereof was the mouth of a small cave into which we could not see any distance. At the bottom of the pit lay a mass of dirty snow and ice to which we did not descend, as the sides of the pit were sheer and smooth, and there was no ladder. This pit seemed to be more of the nature of a gully filled with winter snow, than a true rock cave containing ice.

THE GLACIÈRE DE L'HAUT-D'AVIERNOZ.

Three days after this, on Tuesday, the 21st of September, 1880, we visited the two largest glacières on the

Mont Parmelan, near Annecy, France. At Annecy we inquired at the hotel for a man who knew the Mont Parmelan; and, after finding one, we made our way to Les Villaz, where we spent the night in an *auberge.* Our companion was an odd personage. He was small, about fifty years of age, and looked meek, crushed and hungry. He wore a long black frock coat and black trousers, thin boots and a linen shirt, certainly not the ideal outfit for a cave explorer. Under his care we started early in the morning and toiled up a mountain path some eight hundred or a thousand meters,[1] through woods and pastures, to the higher plateau of Mont Parmelan, in which was situated the first glacière. This was in a great pit, at the bottom of which, on one side, was a big cave. On the side of the pit opposite to the opening, there was a steep rock slope, forty or fifty meters long, whose lower portion was covered with snow. Down this slope we descended with but little difficulty, reaching at the bottom an almost level ice floor which spread over the entire cave and was formed throughout of thick, solid ice. A second and much smaller pit in the roof of the cave opened directly over the ice floor; and under this pit rose a small cone of ice, some two meters high, the only one in this glacière.

The glacière itself was approximately round in shape, and some twenty meters in diameter. At one place the rock wall was broken and we could look into a much

[1] The metric system is used throughout this book, except in a few quotations. Thermometric observations are given in degrees Centigrade.

smaller inner cave or chamber. Into this we could not penetrate on account of a long, narrow crack or hole which yawned in the ice floor for a distance of some five or six meters and continued through the opening into the second chamber. We tried to cut our way along the side of the hole, but had to give it up, finding the ice too hard and our time too short. The crack or hole, whose sides were solid ice, proved conclusively that the ice in this glacière was many meters in thickness, for we could look a long way down into the hole, certainly for ten or twelve meters, until the ice sides disappeared in darkness, without any visible bottom. The hole cannot be spoken of as a crevasse, for, besides not looking like a crevasse, it was certainly formed by other causes than those which form the crevasses in glaciers, since there is, as a rule, no perceptible movement in subterranean ice. Doubtless, the hole was due to the drainage of the cave, which undoubtedly passed off through the hole. There may be, nevertheless, some little motion in the ice of this glacière, for it is evident that it is fed principally directly by the winter snows; which, whether as frozen or melted snow, descend gradually, by the force of gravitation, from the slope of the pit into the glacière.

As for any possibility of this great mass of ice melting away and forming again in any one year, it passes belief; there must be at least the cubic contents of a dozen ordinary houses in the cave, and such a mass could hardly be destroyed or formed again in any such

short space of time as a fall or spring. This is, therefore, probably a permanent or perennial glacière.

THE GLACIÈRE DE CHAPUIS.

Starting out from the Glacière de l'Haut-d'Aviernoz we walked across the plateau of the Mont Parmelan, *en route* for the second glacière. This plateau is a curious rock formation, consisting of what the natives call *lapiaz*, which might be translated "stone-heaps." The plateau is full of great projecting rocks; and myriads of cracks and crevices everywhere rend the surface, and over these crevices one sometimes has to jump. Still, I do not remember any particular difficulty. It was certainly not nearly as bad walking as the taluses of loose rocks one meets at the base of many mountains.

Our guide led us for about an hour across the plateau in a southerly direction, and then, looking over the side of the Parmelan, with a sweep of the arm covering south, west and north, he told us that the glacière lay between those points, but he did not know exactly where. This seemed a rather hopeless prospect, so, as we had no clue to the whereabouts of our prospective hole, we descended to a couple of châlets we saw some two hundred meters below, but which at least were in the direction of Annecy. We followed a goat-herd's path which led to the châlets from the plateau, one of those dangerous grass tracks, where nothing would be easier than to make a slip, and where a bad slip might have unpleasant results. This is, however, just the kind of

place where every one is particularly careful not to slip. We were careful and so reached the châlets all right, and there we found a strong, intelligent boy, who at once pointed out the place where the glacière was, about half way up the slope we had just come down. So we took him with us, leaving our guide at the châlets to await our return.

The entrance to the glacière was in a wall of rock, set at an angle of some thirty-five degrees; at the bottom of this there was some grass. An easy chimney some fifteen meters high led up to the glacière. Up this chimney we climbed. At the top we entered a little cave about two meters deep, by a sort of portal about two meters wide. The cave made an elbow to the right, and passing this we found that it turned to the left and pointed directly into the mountain. The rock went down vertically in front of us, but the boy said we could get down, so having first lowered a candle by a string to see the depth, which turned out to be a perpendicular drop of some four or five meters, with the help of the rope we all climbed down. We were already almost entirely away from the daylight and a few steps took us into complete darkness, except for the light we had from the candle each of us held in his hand.

The fissure led straight into the mountain. It was a couple of meters wide at places, and there we moved along the bottom. In one place it narrowed below to a wedge, and there we progressed either by climbing along one side or by placing one foot on one side and the

other foot on the other. The fissure led downwards as well as inwards. It would have been nothing in daylight to go through it; but in the semi-darkness it was not easy.

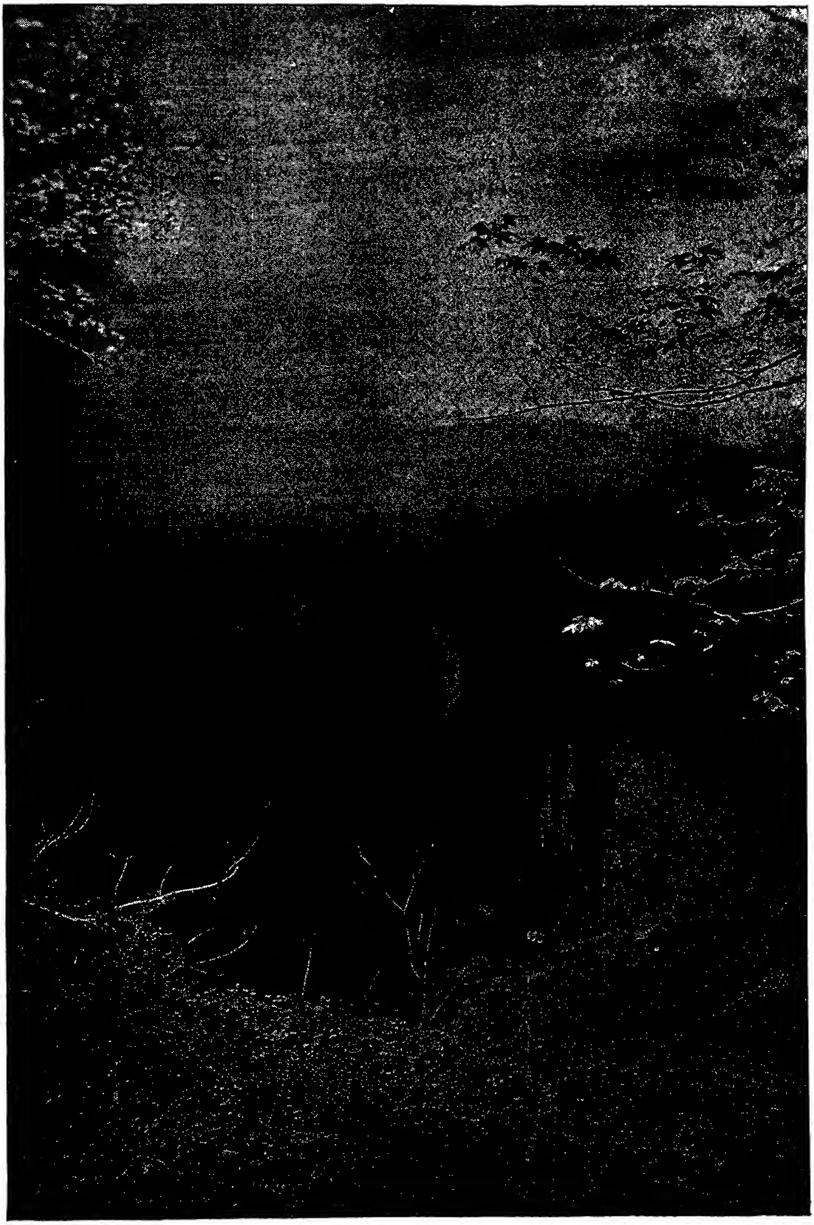
After a descent of some twenty-five meters or thereabouts, we arrived at the glacière, and I have certainly never seen a weirder place. There was a great arched rock dome, perhaps six meters in height, and some twelve in diameter; the floor was a sheet of smooth, slippery ice, at one end curling over, gently at first, afterwards more steeply, to a lower depth; and on the sides were seven or eight ice columns streaming from cracks in the rocks to the floor. Each of these columns was some three or four meters high, and, small at the top and in the middle, spread out at the base into the shape of fans. In the dim candle light and the cold damp atmosphere, the columns loomed up like so many ghosts, and the landscape impression was strange and solemn. The air here seemed perfectly still.

There was another curiosity. The fissure we had come down, at this point some three meters wide, was filled, just beyond the glacière, with pure, transparent water, which formed a little lake: this was perhaps one meter deep, and extended across the fissure, barring further progress. It certainly seems strange that in the same cavern, under nearly the same conditions of temperature, there should be one place covered with a flooring of ice and another filled with water. The explanation, however, is perhaps not far to seek. Over the lake there

was a distinct draught of air. The draught probably melts the ice in summer, if indeed it does not prevent any from forming in winter. There are, so far, no winter observations reported of this cave, yet it would seem to be one which would well repay the trouble.

THE GLACIÈRE DE CHAUX-LES-PASSAVANT.

On the 17th of August, 1894, my brother and I arrived at Besançon, the Vesontio of the Romans, bent on seeing the Glacière de Chaux-les-Passavant or de la Grâce-Dieu, which is not far distant from the town. The hotel we stopped at was pretty bad; the beds were surmounted with those old-fashioned curtains which were of use before the invention of glass windows, but which now only serve to exclude air and ventilation. However, I learnt something of the manners and customs of the country, for on getting down at six o'clock the next morning for breakfast, the first question the waiter asked was: *Quel vin monsieur prendra-t-il?* At seven o'clock we sallied forth in a little open one-horse victoria, with a dull gray sky overhead. Besançon is well down in a valley, so the first five miles of the road were a slow, gradual rise to the surrounding levels. The scenery as we drove along reminded us of Turner's pictures: distant vistas of hills and valleys with factories blowing off their smoke and with tumble-down old houses ensconced in picturesque nooks, just those long-distance effects that Turner loved to paint and which, for some reason, the artists of the present generation have generally



GLACIÈRE DE CHAUX-LES-PASSAVANT.

From a Photograph by E. Mauvillier.

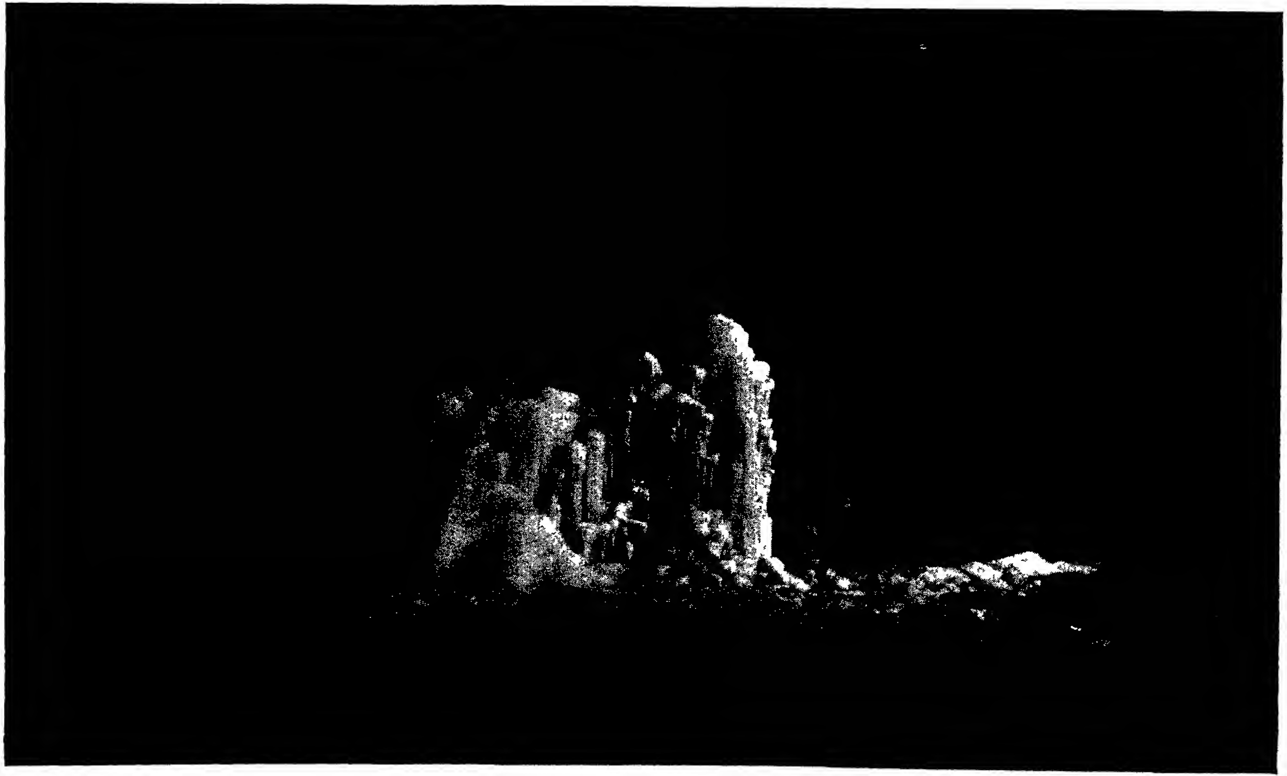
neglected and usually speak of as unpaintable or unpicturesque. There was a row of trees, the whole way, on each side of the road, a bit of practical forestry, the wisdom of which it would be well for Americans to recognize. After our poor horse had pulled us up the long hills, we had an almost level road running in a straight line as far as the eye could see. We saw at least a hundred little hawks, who live on field mice and other rodents, and whose preservation is another evidence of French wisdom. The last four miles of the drive was up a ravine in the woods, near the beginning of which we passed the Trappist convent of la Grâce-Dieu.

Opposite the entrance of the glacière, there is a little restaurant where the peasants come to dance and picnic, and where the few travellers who get to these parts, can obtain a tolerable *déjeuner*. They keep a fair *vin du pays* there, and we had some trouble on the way home in consequence. Our driver, a talkative specimen of the genus and an old soldier of Bourbaki's, told us, on the way out, many things about Besançon during the Franco-German war and of the retreat of the French army into Switzerland; but on the way home, he showed that he evidently was not a member of the blue ribbon army. He first seemed desirous of not taking us back to Besançon, preferring to go in the other direction towards Bale; and afterwards he evinced a violent inclination to go to sleep. We thought we should have to request him to change seats with us, and drive back ourselves, but we obviated the difficulty by plying him with questions as

soon as he began to nod on his box. Eventually, we reached Besançon all right, only once bumping a passing cart, and only once nearly capsizing into a ditch. If Americans can learn some points from Europeans about forestry, I think the latter might get some equally valuable information from us concerning the use of water, externally and internally.

The good lady at the restaurant acts the part of the old-fashioned cave dragon, and we had to appease her by handing over four *sous* as a preliminary to exploration. She also had a sign up, saying that no one is allowed to break off or take away any ice, which must sadly interfere with the tourists' privilege of bringing away specimens.

The entrance of the glacière was surrounded by woods, which formed a natural rampart to anything like wind. As we stood facing the glacière a great pit opened before us, with a slope about one hundred and thirty-five meters long leading to the bottom. This slope is at first gentle in its gradient, but lower down it steepens to an angle of some thirty degrees so that we were glad to resort to the trail which descends in regular Alpine zigzags. In one place, on the right hand, there were the remains of a stone wall with a door, and local tradition relates that in former times there was a sort of fortified habitation there, which was used in war times as a place of retreat. The lower part of the slope is covered by a protecting roof of rock which, thin at the rim where it is edged with forest, gradually slopes downward overhead so that at the mouth of the glacière we looked back and



ICE STALAGMITES, CHAUX-LES-PASSAVANT.

From a Photograph by E. Mauvillier

up what might be described as an immense tunnel. The lower part of the slope was a mixture of broken rocks, mud and ice: the last, however, seemed to be all on the surface, although it was impossible to determine whether it went to any depth.

At the base of the tunnel we found ourselves on the threshold of an immense, almost circular cave, with a diameter of some fifty meters, rising overhead into a regular vault or dome about twenty-seven meters in height. The entrance to the cave is so large that plenty of day-

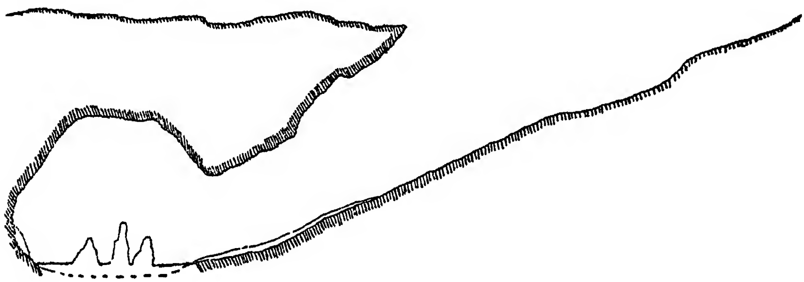


FIG I [2] VERTICAL SECTION OF CHAUX-LES-PASSAVANT.

light is admitted, and the whole cave easily examined. The rocks are of a yellowish brown hue, and I could not help thinking of Nibelheim in Richard Wagner's Rheingold.

The bottom of the cave was entirely covered with a flooring of ice. How thick this flooring was there was no means of judging, as there were no holes, but it must

[2] The figures in this book are rough sketches, without pretense at accuracy of measurement, and are only explanatory of the text.

have been at least two or three meters thick in places. At the back of the cavern, directly facing the entrance, one magnificent frozen water fall streamed from a fissure. It was perhaps five meters high, and began to take the fan shape from its origin. The base was about four meters wide, and did not rest on the ice floor, but on a sloping rock extending out from the side of the cave.

Perhaps the most remarkable feature of all, were six or seven great ice stalagmites, shaped like cones or rough pyramids, which rose on the floor of the cave. One of these was at least five meters in diameter and six in height, and seemed perfectly solid. In the case of two of the others, however, the cones were broken on one side, revealing in each the stem and branches of a young pine tree. These evidently had been planted in the ice and round them the columns had grown. Whether all the ice cones were thus artificial in their origin I could not determine, but it seemed probable that they were the result of years of undisturbed accretion and growth. In both the cones where the break on the side gave a view into the interior, the dark blue-green color of deep glacier crevasses was present.

A pool of water, perhaps thirty centimeters in depth and three or four meters in diameter, lay at one place on the ice floor. The whole cave was damp and the ice in places decidedly slushy, in fact all the signs showed that it was thawing. In the case of this glacière as well as in those of the Mont Parmelan, it seemed clear that

ICE STALAGMITES, CHAUX-LES-PASSAVANT.

From a Photograph by E Mauvillier

it must be in the winter months that the formation of ice takes place.

DÓBSINA JEGBARLANG.

The cavern of Dóbsina, in the Carpathian Mountains, is easily reached either from Poprád to the north, or from Dóbsina to the south. The hotel at Poprád is better, however, than the inn at Dóbsina, where my brother and I spent two nights. It was decidedly primitive. The food was not so bad, but the pigs ran round in the courtyard, and one morning a gypsy band woke us at half-past three o'clock by playing in front of our windows, in dreadful wailing tones, which were most irritating at that hour. At the proper time, however, Hungarian gypsy music,—despite the fact that none of the players ever seem to look at the leader, and that each man appears to play the tune he likes the best,—is strangely fascinating.

Dóbsina itself lies in a hollow, surrounded with well-wooded hills, the general appearance much resembling some of the valleys of the White Mountains of New Hampshire. My brother and I started from Dóbsina on the morning of the 27th of July, 1895, at half-past seven o'clock, in a little open carriage with excellent horses and a Hungarian driver in national costume. He was a nice fellow, but he did not understand a word of German. The road reminded us of some of our own mountain roads, as it was rough, full of holes and partly washed away by the rains. We first ascended to the crest of the surrounding hills and then descended to the

Stracena Thal, a wild limestone valley covered with fine forest. Two hours and a half driving landed us at the hotel-restaurant near the cave, at which I should certainly stop on another visit. It was half an hour's stroll thence, through beautiful woods, to the cavern's entrance. Northwards in the distance the Tátra Range was visible, a set of sharp bare rock peaks, at whose base, ensconced in pine forests, is situated the famous Hungarian summer resort of Tátra Füred, which much resembles Bar Harbor.

The entrance to the cavern is enclosed by a fence with a gate, and here the Dóbsina people have a high tariff and take toll from tourists. At the gate, we waited for half an hour, until a sufficient number of persons had arrived to form a party. This mode of visiting the cave rather detracts from the pleasure, even though it does away with all difficulty and makes the beauties of Dóbsina accessible to everyone. It was also necessary to wait long enough to cool off thoroughly before entering, on account of the icy air of the cavern, where heavy winter clothes are indispensable.

The entrance to Dóbsina faces nearly due north. It is small, perhaps two meters wide and three meters high, and is perfectly sheltered from any wind. The sudden drop in temperature at the entrance was startling; in fact it was the most extreme change I have noticed in any cave. Within the length of an ordinary room, say in a distance of five meters, we passed from an extremely hot summer morning to the chill of a mid-winter afternoon. A slight

air current, perhaps, issued from the entrance, as we observed a faint mist there. At the rock portal there was ice on the rocks overhead, and underfoot was the beginning of the huge mass of ice which almost fills the cavern. A descent down eighteen wooden steps landed us at the beginning of a great ice floor, in what is called the *Grosser Saal.* It is a magnificent cave. The floor is a sheet or rather a mass of solid ice, the surface of which is level enough in one place to permit of skating; in other

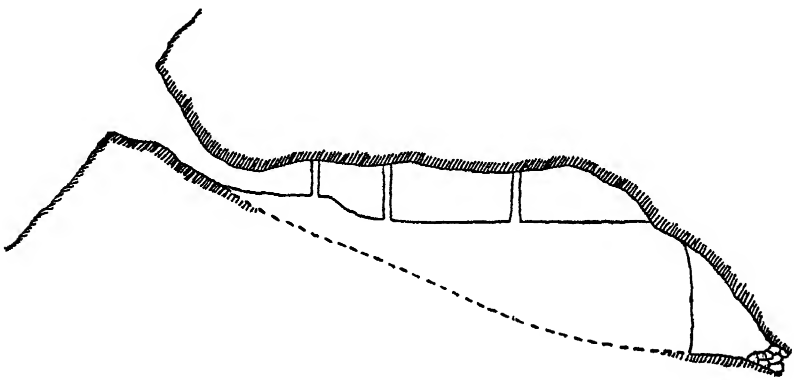


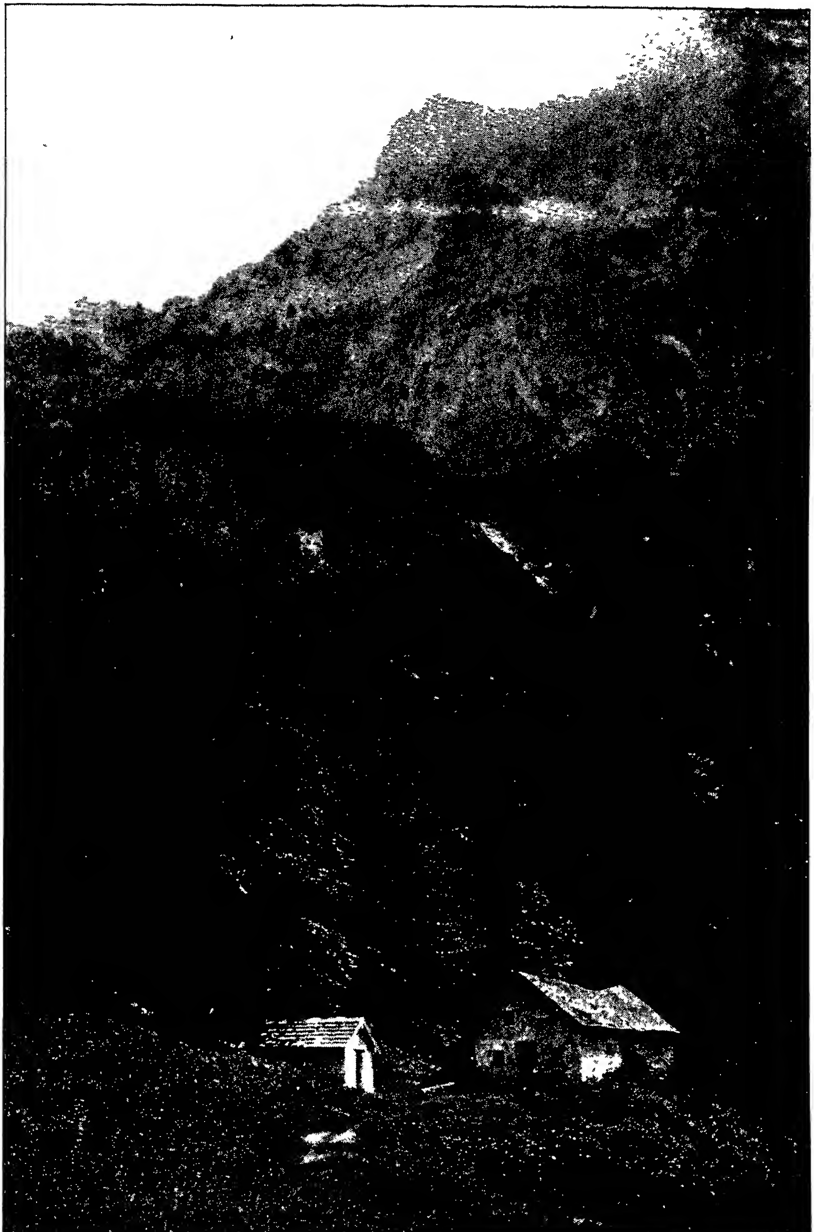
FIG 2 VERTICAL SECTION OF DÓBSINA.

spots it is sloping and covered with small ice hillocks. The ice is solid throughout, without any holes or cracks. Several fissure columns stream to the floor from cracks in the sides. Joining the roof to the floor are numerous big ice stalactites, which form frozen pillars and columns. These are from eight to eleven meters in height, and some two to three meters in average breadth and width. Nearly translucent, they are covered with all sorts of icy ornaments hanging about them in tufts and fringes; they are

beautiful in their shapes, as well as in their white and blue colors. One of these columns is called the *Brunnen*, because until about ten years ago, a small stream dribbled continuously from the roof and cut a channel across the ice floor; but now the stream has solidified into the pillar, and the channel is filled up, although it can still be traced in the ice.

The cavern is lighted by electricity, which has the merit, even if it brings in an element of artificiality, of clearly revealing one of the chief glories of Dóbsina. This is the rime or hoar frost, which in the shape of ice or snow crystals, covers the entire limestone roof, and, reflecting the electric light, shines like frosted silver. Some of these frost crystals seem to be precipitated to the floor, and in one place I found a small sheet of them, perhaps two meters in width each way, which looked and felt like genuine snow. The general color effect of all this upper cave is white, although there is some blue in the ice, and gray and brown in the rocks and shadows. It would not be much of a misnomer to call Dóbsina "the great white cave."

The ice extended to the sides of the cave except in two places. Here there were holes in the ice, bridged by low rock arches. We passed through one of these and descended by a wooden staircase some eighty steps, afterwards returning up through the other arch by another staircase. At the bottom we stood in a magnificent gallery named the *Korridor*, formed by a solid wall of ice on one side and by a wall of limestone rock on the other.



THE LOWER ROSITTEN ALP AND THE UNTERSBERG.

The ice wall is the lower portion of the ice floor; the rock wall is the continuation of the roof. For the entire distance the ice wall rises almost perpendicularly some fifteen meters in height, while the rock wall arches overhead.

The bottom of the *Korridor* was filled with blocks of fallen limestone, through which any water drains off, and on which there was a wooden walk, so that we circled round the ice with the greatest ease. At one place on the limestone wall hung a cluster of big icicles, which, from their shape really deserved the name they bear, of the *Orgel*. At another place a hole, some six or seven meters deep, was hewn, in the form of a small chamber, directly into the ice mass. This is the *Kapelle*, where we performed our devotions by leaving our visiting cards on the floor. Near the middle of the *Korridor* the ice mass bulges out and extends to the limestone wall, breaking the whole *Korridor* into two parts, the western portion about eighty meters, and the eastern about one hundred and twenty meters long. This necessitated cutting a tunnel about eight meters long in the ice to get through. The color of the *Korridor* is a darkish gray and is much more sombre than that of the *Grosser Saal*. A remarkable feature of the ice wall is the fact that distinct bands of stratification are visible in the ice in many places. Why the *Korridor* is not filled up with ice and why the ice is perpendicular for such a distance are questions I am unable to answer satisfactorily; but it is probable that the temperature of the rock walls is sufficiently high to

prevent ice from forming in winter or to melt it in summer if it does form in winter.

The air in Dóbsina seemed still, and scarcely felt damp. In one or two places in the *Grosser Saal* there was a slight sloppiness, showing incipient signs of thaw. In the *Korridor* it was freezing hard.

THE KOLOWRATSHÖHLE.

The Kolowratshöhle is situated on the north slope of the Untersberg, near Salzburg, at an altitude of 1391 meters. My brother and I visited it on the 2d of August, 1895. We had one of the patented guides of the district, Jacob Gruber by name, in regular Tyrolese dress, with gray *jacke* and black chamois knee breeches. We left Salzburg in the early morning in an *einspänner* and drove to the foot of the Untersberg in about an hour, whence, by a rough path passing by the Rositten Alp, we ascended to the cave in about three hours. The last hundred and sixteen meters of the path were cut across some moderately steep rock slabs and a perfectly unnecessary iron hand-railing affixed.

The entrance faces northeast. Here there must have been a slight draught of cold air moving outwards, the effect of which was perceptible to the eye, as at the point where the cold inside air met the quiet warm outside air. a faint mist was visible. From the entrance, a sharp slope, set at an angle of about forty degrees, led to the lowest point of the cave. The upper half of this slope was still covered with the winter snow which had blown or had

THE ENTRANCE OF THE KOLOWRATSHOHLE.

slid in. We descended on the right hand edge of the snow by means of some steps cut in the rock by the *Deutschen-Oesterreichischen Alpen Club.* These steps were covered with a sticky, red mud, which left almost ineradicable stains on our clothing, and as there was also ice in places, they were decidedly slippery.

At the bottom of the slope we were at the lowest point of the cave, to which all the water flowed, and

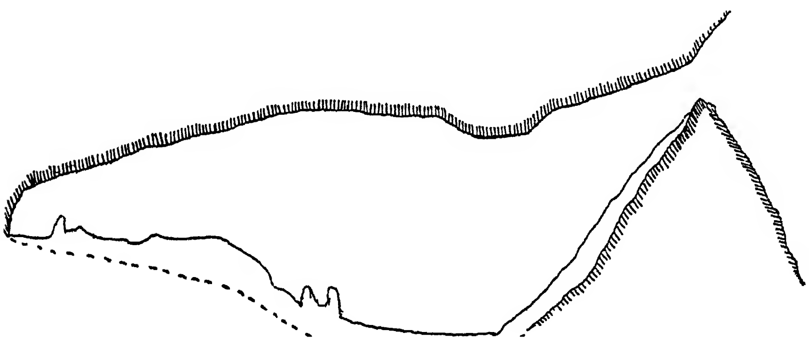


FIG 3 VERTICAL SECTION OF THE KOLOWRATSHÖHLE.

where it drained off into a crack with a loud gurgling noise. Back of us was the daylight streaming through the entrance; opposite to us was first an ice floor, then a great ice slope, which came down from the further end of the cave. The ice was transparent and of a pale ochre-greenish hue, and filled the entire width of the cave. There is a streak of iron, probably, through the limestone, which in places tints the rocks a dull red. The color impression is a dull green-red, and, on account

of the size of the entrance, the light effect is only semi-subterranean.

The ice floor was covered with a layer of slabs of ice, eight or ten centimeters thick, which, earlier in the year, had evidently had water under them. The ice wall or ice slope consisted of two big waves, one above the other, the lower set at an angle of about ten degrees, the upper set at an angle of about twenty-five degrees. To get up the upper wave required about twelve steps cut with the axe. Behind the upper wave, five or six fissure columns streamed out to the beginning of the ice. One ice stalactite, at least two or three meters long, overhung the ice floor, and Gruber said about this: "Well, I wonder it has not fallen yet: they seldom last as late in the year," a confirmation of what was clearly evident, namely, that the whole cave was in a state of thaw.

In two places there was a strong, continuous drip from the roof to the ice floor, which formed, in each case, what I can only call an ice basin. These basins were nearly circular; one was about four meters, the other about two, in diameter. Around about two-thirds of the rim of the larger one, ice rose in a surrounding ring two or three meters high, suggesting that earlier in the year this basin was a cone, and possibly a hollow cone. The depth in the ice floor, in both cases, was about one and a half meters, and each basin contained some thirty centimeters in depth of water. They reminded me of the rock basins one sees in

TOP OF ICE SLOPE, KOLOWRATSHOHLE.

mountain torrents, where an eddying current has worn smooth all the edges of the rocks. From the larger of these basins, a channel as deep as the basin ran to the lowest point of the cave. This channel was cut out by the overflow, which ran through it in a tiny stream.[3]

THE SCHAFLOCH.

The Schafloch, on the Rothhorn, near the Lake of Thoune, is one of the biggest glacières in the Alps. On the 15th of August, 1895, after early coffee, made by the *portier* of the Hotel Belvedère at Interlaken, I drove to Merligen, on the north shore of the lake, with Emil Von Allmen, an excellent guide. We left Merligen on foot at a quarter before seven, and, making no stops on the way, reached the Schafloch at ten minutes past ten. The path mounts gently up the Wüste Thal, which higher up is called the Justiz Thal. The track through the latter is almost on a level, over grassy alps. On the right hand rise the steep, almost dolomitic, limestone cliffs of the Beatenberg. On the left is the range of the Rothhorn, with steep grass and forest slopes below, and

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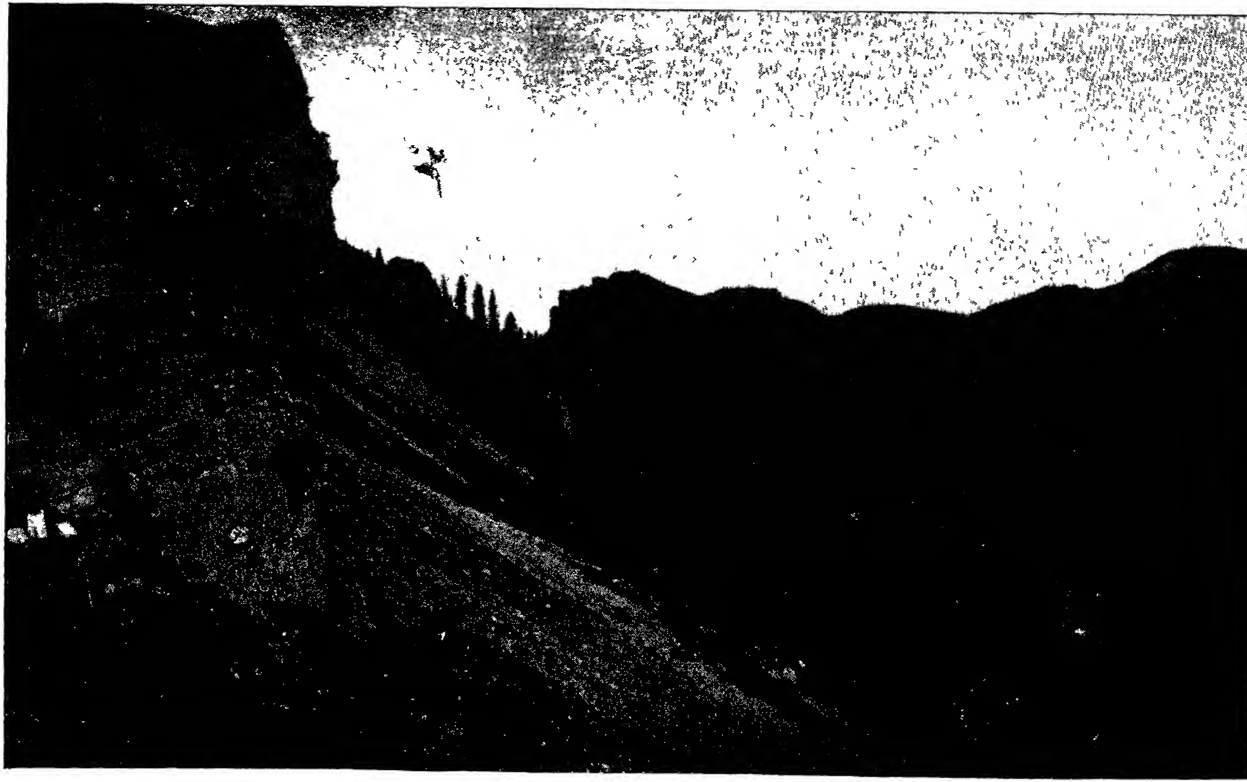
[3] The photographs of the Rositten Alp, of the entrance of the Kolowratshöhle, and of the interior of the Kolowratshöhle, were made for me on the 16th of July, 1896, by Herr Carl Hintner, Jr., of Salzburg. The two latter photographs are, I believe, the first good ones ever obtained of the inside of the cave. They were taken without artificial light on quick plates; the best of the two received an hour and a half, the other two hours' exposure. The photographer said at first that it was not possible to succeed, and it was only by promising to pay him in any case, that he could be induced to try.

limestone cliffs above. The last hour of the walk was up these slopes, by what Baedeker calls a "giddy path." By leaving the word "giddy" out, his description is accurate. The cavern is at the base of the limestone cliff, and the grass slope extends up to it.

The entrance to the Schafloch is at an altitude of 1752 meters: it is a fine archway, and a low wall is built partly across it. In front of this, we sat down and consumed our chicken and cheese, and that best of a traveller's drinks, cold tea. The day was windless, and when I lighted a cigar, to see whether there was any draught at the entrance, the smoke rose straight up, showing that the air was perfectly still. When we were sufficiently cooled off, we entered the cave. The entrance faces east-southeast, but after about ten meters the cavern takes a sharp turn to the left, forming a sort of elbow, and runs about due south, constantly descending in an almost straight line. For the first eighty meters or so, the floor was covered with blocks of fallen limestone, among which we had to carefully pick our way. Then we began to find ice, which, a few meters further on, spread out across the entire width of the cave, with a gentle slope towards the left. The surface of the ice was rather soft, and the whole cave was evidently in a state of thaw. A few scratches with the axe—the most invaluable friend in an ice cave—were necessary at one place to improve our footing. It would have been impossible to move here without a light, and I carried our torch, made of rope dipped in pitch, which occasionally dropped black reminders on my clothes. We



AT THE ENTRANCE OF THE SCHAFLOCH.

were in the middle of a great ice sheet to which several fissure columns streamed. On the right hand a beautiful ice stalactite flowed from the roof to the floor; it was some five meters high, and perhaps seventy-five centimeters in diameter, and swelled out slightly at the base. On the left hand were three or four ice stalagmites, shaped like pyramids or cones.

One of these cones was especially remarkable. It was at least five meters high—Von Allmen said eight—and at the bottom was about four meters in diameter. The base of this cone was entirely hollow. There was a break on one side by which we could enter, and we then stood on a rock floor with a small ice dome or vault overhead. I have seen no other hollow cone like this. The guide lighted a red Bengal fire inside, when the whole pyramid glowed with a delicate pink light, resembling *Alpenglühn*. Near this cone stood the half of another ice cone. It was quite perfect, and the missing half was cut off perpendicularly, as if with a huge cleaver. A hollow in the base of the remnant showed that this cone must have been originally also a hollow cone, and its destruction was probably due to the change in the temperature of the drip from the roof, at the setting in of the summer thaw.

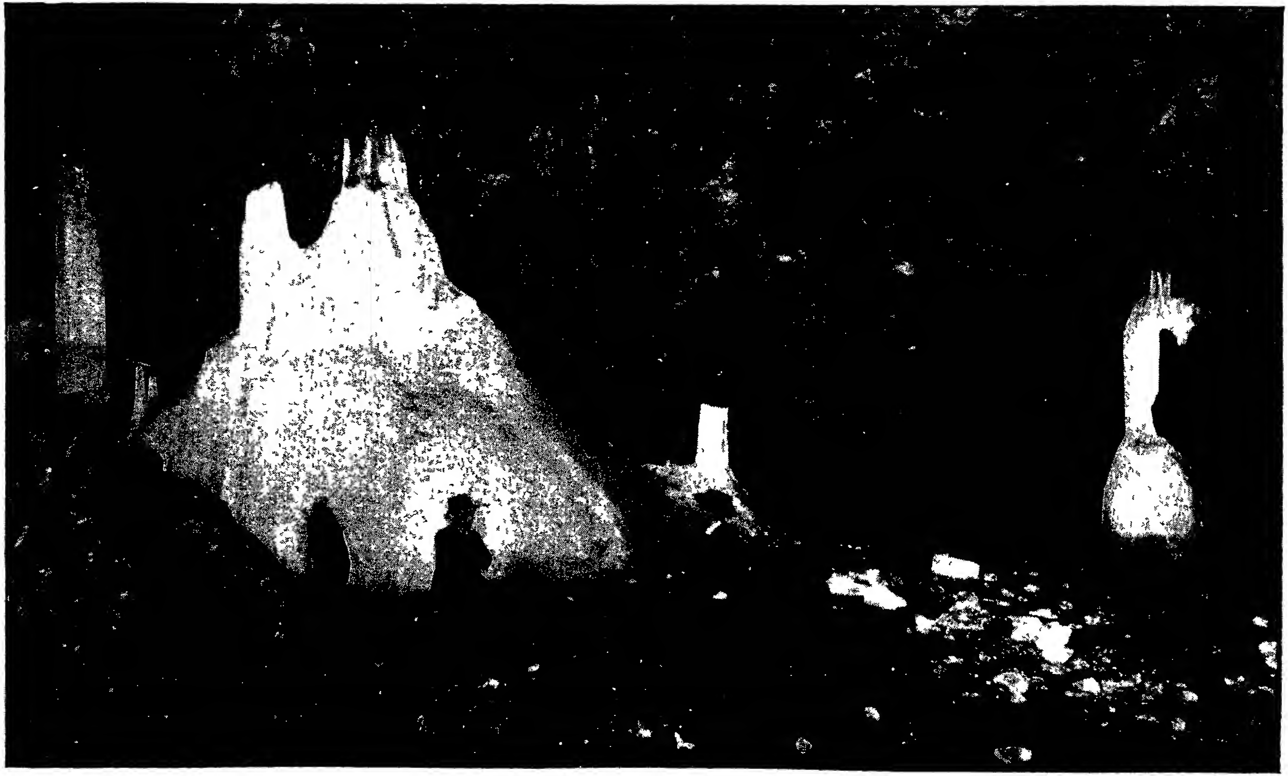
Just beyond the cones, the ice floor steepens and curls over into a big ice slope, one of the finest I have seen. Von Allmen spoke of this as *der gletscher*, an expression I never heard applied elsewhere to subterranean ice. On the right side, the slope would be difficult to descend in the darkness. On the left, the slope is gentle

and a rock juts out a little way down. Von Allmen insisted on roping—an unnecessary safeguard—but he said: "If you slip, you will probably break an arm or a leg, and then we shall be in a nice mess." He then cut about twelve steps in the ice, down to the rock, while I shed light on the performance with our torch. We were so completely away from daylight that black was the predominating color; and even the ice was a dark gray, and only appeared white in the high lights. Below the rock, we found a narrow strip on the left side of the ice slope free from ice and blocked with boulders, over which we carefully picked our way down. At the bottom, the ice expanded into a level surface, stretching nearly to the end of the cave. There were only a few fissure columns in this part of the cavern, where the most remarkable feature was the cracks in the rock walls, which were so regular in formation that they almost looked like man's handiwork. The rocks are free from stalactites, and in fact stalactites seem a good deal of a rarity in glacières.

On retracing our steps, we saw, when the first glimmers of daylight became perceptible, the rocks assume a brilliant blue color, as if they were flooded with moonlight. This effect lasted until near the mouth of the cavern.

DÉMÉNYFÁLVA JEGBARLANG.

A little west of Poprád, in Northern Hungary, on the railroad between Sillein and Kassa, is the village of Liptós Szt. Miklós, to which place I journeyed on the



HOLLOW CONE AND FISSURE COLUMNS, SCHAFLOCH.

12th of June, 1896. The conductor was the only man on the train or at any of the stations who would admit that there was a glacière at Déményfálva, and that it was feasible to get into it: every one else professed entire ignorance on the subject. It is perhaps, worth noting at this time that it is always difficult to get any information about glacières; in fact, the advice about cooking a hare might well be applied to glacière hunting: first catch your glacière.

The scenery between Sillein and Miklós was picturesque. The hills were covered with forest. In one place, the railroad ran through a beautiful mountain gorge alongside a river, where a number of rafts were floating down. There were also some primitive ferries, where a rope was stretched across the river, and the force of the current carried the ferryboat across, once it was started. Many peasants were at work in the fields; often in squads. White, blue, brown, and a dash of red were the predominating colors in their dress. The men wore white trousers, made of a kind of blanket stuff, and a leather, heelless moccasin of nearly natural shape. Almost all the women had bare feet; those of the older ones were generally shaped according to Nature's own form, while those of the younger ones were generally distorted from wearing fashionable shoes. We went past several villages of huts with thatched roofs, something like the Russian villages one sees beyond Moscow, only less primitive.

The inn at Miklós was poor, and as at Dóbsina, the pigs lived in the yard and occasionally came for an

interview under the covered doorway. Inquiries elicited the information that Déményfálva could be reached by carriage, so I engaged one at the livery stable. The owner told me that about twenty years before, he leased the glacière and carried on a regular business in supplying Buda-Pest with ice. He had thirty lamps put in to give light to the workmen, who brought up the ice in baskets on their backs.

At half past five o'clock next morning the carriage, which was innocent of paint, lined with a sort of basket work and without springs, but certainly strongly built, stood at the door. A boy of about eighteen years of age, who could speak German, went along as interpreter. The morning was dismal, and, every quarter of an hour or so, a shower of thick mist fell and gradually made us damp and uncomfortable. After about twenty minutes on a pretty bad road, we came to a place where there was a fork, and the driver turned to the left, over a track which consisted of two deep ruts through the fields. Soon after, we heard some shouting behind us, and a fierce-looking man, in a leather jacket and carrying a large axe, came up and abused the driver. He was not an agreeable person; however, presently he simmered down and began to smile. It turned out that he was a *wächter*, that is, a guardian of the fields, and that we were trespassing. The driver meekly promised to return by the other route, and we went on our way in peace. After awhile, we drove into some woods and then into a mountain gorge, with forest-covered slopes

ON THE ICE SLOPE, SCHAFLOCH.

at the base and with limestone cliffs jutting out above. Here we came to the cottage of the *wächter* or *förster* of the surrounding woods, who also acted as guide to the cave, for the few tourists who came to see it; and when he heard of our destination, he at once slipped on a second ragged coat, took a woodman's axe and started on foot, going much faster than the carriage. This was not surprising, for the road resembled nothing but the bed of a mountain brook, a mass of boulders with ruts between them. This highway was made by the peasants driving their carts over the plain in the same place, and as the soil was cut away, the boulders appeared; and over and among these we went banging along, and we were jolted about and bumped into each other, until every bone in my body ached.

At a quarter past seven o'clock we came to another house in a little glade, where the carriage stopped; and on asking the *förster* for his name, he wrote down in my note book, in a clear well formed hand:—Misura, Franz. From the glade, ten minutes' walk on a mountain path, up an easy slope, took us to the entrance of Démenyfálva. It is about two meters wide by three quarters of a meter high. We passed through and entered a large chamber, well lighted from the right by another opening, which is higher up and bigger than the entrance. The air in this chamber was at about the same temperature as that of the outside air, and, on our return from the nether world, it seemed positively balmy. In the floor at the end of the chamber, a small pit yawns open. It is perpendic-

ular on three sides and set at a sharp angle on the fourth. A wooden staircase of some two hundred steps, many of which are sadly out of repair, leads nearly straight down this slope to the glacière.

After descending about eighty steps of the staircase, bits of ice appeared on the walls and floor and after some thirty steps more, a lateral gallery opened to the right, and into this we turned. This may be called the upper cave or story, for in Démenyfálva—besides the entrance chamber—there are practically two stories, the upper one of which is mainly ornamented with stalactites, the lower one with ice. There was a little ice on the floor from which rose some small ice columns, perhaps fifty centimeters in height. The cave or gallery had a gentle downward slope and turned towards the left. After some little distance, we came to another wooden staircase, of ten or twelve steps, quite coated over with thick, solid ice. Misura had to cut away at it for several minutes, before he could clear the steps enough to descend. This was in fact the beginning of an ice wall, the *Eiswand* or *Eismauer*, which, turning to the right, flowed through a rock arch to the lowest cave. The rock arch or portal was some three meters wide and two meters high, and a fringe of beautiful organ-pipe like icicles hung on it on the right hand. Just beyond the portal the ice sloped steeply for a couple of meters; then it became level and on it rose a little pyramid, a meter and a half in height perhaps, and a column; then the ice sloped away again to the lower cave.

IN THE REAR OF THE SCHAFLOCH.

We then continued our course beyond the rock portal along the upper cavern for about two hundred meters. It was a fine large gallery or passage and during the first fifty meters or so, we found numerous small ice cones, perhaps a hundred of them, from tiny little ones to some about forty centimeters in height. Many of these were columnar in form, nearly as large at the top

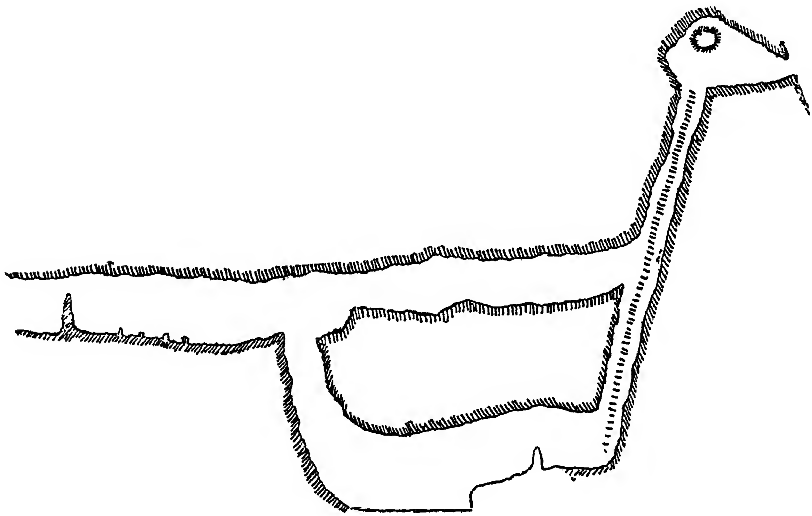


FIG. 4. VERTICAL SECTION OF DÉMENYFÁLVA.

as at the base: in some cases the top was flat, and the columns then looked almost as if an upper portion were sawn off. I have seen this shape of column nowhere else. In places there were slabs and bits of ice on the floor. The last hundred meters of this upper cave was free from ice and was exceptionally dry. It was formed of a pale yellow limestone rock, almost dolomitic in color, and many stalactites, in their thousand

various shapes, hung from the roof and on the sides. In one spot, one big limestone stalagmite towered up directly in the middle of the gallery. We did not go to the end of the cave, where ice has never been found.

Retracing our course past the rock portal to the entrance pit, we descended on the long staircase for some eighty steps more, the amount of ice on the rocks steadily increasing. In places, frost crystals had formed in small quantities on the roof and walls. At the bottom of the pit, another lateral gallery, directly under the upper gallery, opened to the right. Entering this, we passed over broken limestone débris, which seemed to overlie a mass of ice. Limestone stalactites were noticeable all through this lower cavern, and frost and icicles had sometimes formed over them, in which case the ice stalactite assumed the form of the limestone stalactite. Advancing a few meters, we went by, on our right hand, an ice pyramid of a couple of meters in height. Just beyond this, the cave turned to the left like the upper cave, and we descended to a level floor of transparent ice, into which we could see some distance. At this spot, numerous icicles, generally of inconsiderable size, hung from the roof and on the sides of the cavern.

At the further end of this ice floor or ice lake we reached an ice slope, the *Eiswand*, which flowed to the ice floor from the upper cave in several waves. It was some six meters wide and twenty-five meters long; and it was not steep, perhaps fifteen degrees in the steepest portions. On the slope some old, nearly obliterated steps were visi-

ble, and at these Misura proceeded to cut, and with torch in one hand and axe in the other, gradually worked his way up, until he once more reached the level spot whence we had looked down the ice slope. Here he stood waving his torch, a proceeding indeed he did constantly throughout the trip, for he seemed exceedingly proud of the beauties of his cavern. This waving of torches, however, is exceedingly foolish, as their smoke quickly blackens stalactite, and in fact nothing but candles and magnesium wire should be carried for lighting purposes underground. The ice of the ice slope was hard, gray and opaque, quite different from that of the ice lake. The ice floor is formed of new ice, which is gradually refilling the place from which Misura said the ice for Buda-Pest was taken out twenty-five years ago. To prove this assertion, he called my attention to the side of the lake directly opposite the ice slope. At that spot, under the limestone rubbish over which we came, there was an outcrop of perpendicular opaque ice about a meter high. Misura said that the workmen began to cut at the ice slope and that they dug out a couple of meters in depth from the ice lake, until they had cut back to where the vertical outcrop was standing.

The explanation seemed to be in accord with the facts, and if so, it would go to show that the ice in this cave is of slow formation and great permanency; as seems also proved by the steps on the ice wall, which—we were the first party in the cave in 1896—had remained over from the preceding summer. Misura told me he had never seen so much

ice nor seen it so hard as during our visit, and he added that there was generally water on the ice lake, and he thought there would be some in two or three weeks more. The greatest quantity of ice in the upper cave was at the head of the ice-slope, and it would seem as though there must be cracks or fissures in the overhead rocks there, through which the water is supplied to feed the ice, not only that of the upper cave, but also the larger portion of that of the lower cave.

The heavy winter air would naturally sink down into the entrance pit to the lower cavern, and some of it diverge into the beginning of the upper cavern, which at first is distinctly a down slope. A little beyond the portal at the head of the ice slope, the upper cave is either horizontal or in places slightly ascending. Probably this prevents the cold air from entering further, and probably also, the heat of the earth neutralizes the cold air of winter beyond a definite spot.

The air in the cave seemed absolutely still throughout; it was also extremely dry, undoubtedly because melting had not yet begun. The icicles evidently were formed by the slow drip freezing as it descended, and there were no perceptible cracks nor fissures in the rocks underneath them. The facts seem to me to prove that neither evaporation nor regelation can be the factors at work in making the ice and we may deduce an important rule therefrom. When a cave is dry, then the air is dry; when a cave is wet, then the atmosphere is damp. In other words, the state of dryness or dampness of glacière

atmosphere depends on how much the ice is thawing and parting with its moisture.

On our return to the base of the long staircase, and while we ascended it, we had an exquisite moonlight effect, much resembling the one at the Schafloch.

THE FRAINER EISLEITHEN.

About two hours by rail, north of Vienna, is the village of Schoenwald, to which I journeyed on June the 15th, 1896. At the railroad station there was a K. K. Post Omnibus in waiting, which, when it was packed with passengers and luggage, drove over to Frain in an hour. The admirable road lies across a rolling plain, until it reaches the brink of the valley of the Thaya, to which it descends in long Alpine zigzags. On the bluff overlooking the opposite side of the river, there is a fine *schloss*.

I secured the seat next to the driver and questioned him about the Eisleithen. Although he had driven on this road for five years, without visiting the Eisleithen, yet he was positive that they were warm in winter, but cold in summer. He said more than once: *Desto heisser der Sommer*, *desto mehr das Eis*, and in fact was an emphatic exponent of the notions generally held by peasants, which some *savants* have adopted and tried to expound. At Frain, I applied at the little hotel for a guide, and was entrusted to the care of the hotel boots. He was an intelligent, talkative youth, but he insisted also that "the hotter the summer, the more ice there is." However,

he was polite, and made up for any shortcomings by always addressing me as *der gnädige Herr.*

The day was hot, so it took us three-quarters of an hour on foot, along the valley of the Thaya, to reach the base of the bluff where the Eisleithen are situated, at an altitude of about four hundred meters. The hill-side is covered with patches of scrubby forest; and towards the summit, the entire mass of the hill is honey-combed with cracks and the rocks are much broken up. After about ten minutes' ascent up a little path, we came to small holes, from each of which a current of cool air poured out; these holes seemed fairly horizontal, and the temperatures were high enough to prove that there was no ice within. A little further on, we came to a hole or tiny cave among a pile of rocks, where there was a painted sign: *Eisgrube.* It went down from the mouth, and I put my hand well in, but, beyond the length of my arm, I could neither see nor measure its shape or depth. The air felt cold, but was nowhere near freezing point; nor was it possible to determine whether there was a draught: it may or may not be a wind cave. Not far from this, there were two gullies, each terminating in a small cave. The first gully was planned somewhat like certain traps for wild animals, that is, it narrowed gradually from the entrance, then became covered over; and then dwindled, after some four meters more, into a small descending hole, the end of which we could not reach. But we got in far enough, to come to large chunks or slabs of ice plastered about on the floor and sides. In this cave,

which was sheltered against sun and wind, the air, as tested by the smoke of a cigar, was motionless, and the cave seemed unconnected with any air current. The second gully terminated in a somewhat larger cave, whose floor was well below the entrance; no ice was visible, however, although the air was still and the temperature low. This cave may or may not be a glacière; but surely it is not a cold current cave.

These Frainer Eisleithen certainly offer an interesting field to anyone studying subterranean ice, from the fact that there are, in the same rocks, caves without apparent draughts in summer and containing ice, and caves with distinct draughts and no ice. The problem seems more intricate than is usually the case, but the solution is simply that the two classes of caves happen to be found together.

THE EISHÖHLE BEI ROTH.

The Eifel is one of the bleakest districts of Central Europe, and to one entering it from the vineyards and the well-inhabited basin of the Rhine, the contrast is impressive. The railroad rises gradually to a land of comparatively desert appearance, with rocks and trees on the heights and a sparse cultivation in the valleys. But, if the country is unattractive to the agriculturist, it is interesting to the geologist, on account of the great number of extinct volcanoes. Almost in the centre of the Eifel is the little town of Gerollstein, famed for the *Gerollsteiner Sprudel,* which gives forth an effervescence

undreamed of by anyone, who has not visited the birth place of some of these German table waters.

About an hour's walk from Gerollstein, on the side of a small hill, is situated the little Eishöhle bei Roth, named after a neighboring village. I went to this place, on the 25th of June, 1896, with a young boy as guide. The cave is sheltered from the wind by a wood around it, among which are many large trees. It is at the base of a wall of piled up lava, or at least volcanic, rocks which form a sort of cauldron. The entrance is a small tunnel some five meters long, which goes straight down at an angle of about twenty-five degrees and then turns sharply to the left. At the turn, the cave may be perhaps one meter in height. We did not go beyond this spot, where the air was icy and the temperature subnormal, as the tunnel was blocked up by a large boulder, which had evidently recently fallen from the rocks in front. There was no ice, as far as we went, and the boy said it began three or four meters further in. He told me that there was no ice in the cavern in winter, but admitted that he had not entered it at that season, so that was hearsay. He had heard also that the ice was sometimes taken out for sick people, but otherwise it was not used.

It seemed to me that the conditions at Roth show that the ice is formed by the cold of winter alone: the cave is well below the entrance; it is the lowest point of the surrounding cauldron of rocks and all the cold air naturally gravitates to it; it is sheltered by rocks

and trees from wind or exposure to the rays of the sun; the tunnel faces nearly due north; and the water necessary to supply the ice, easily soaks between the lava blocks.

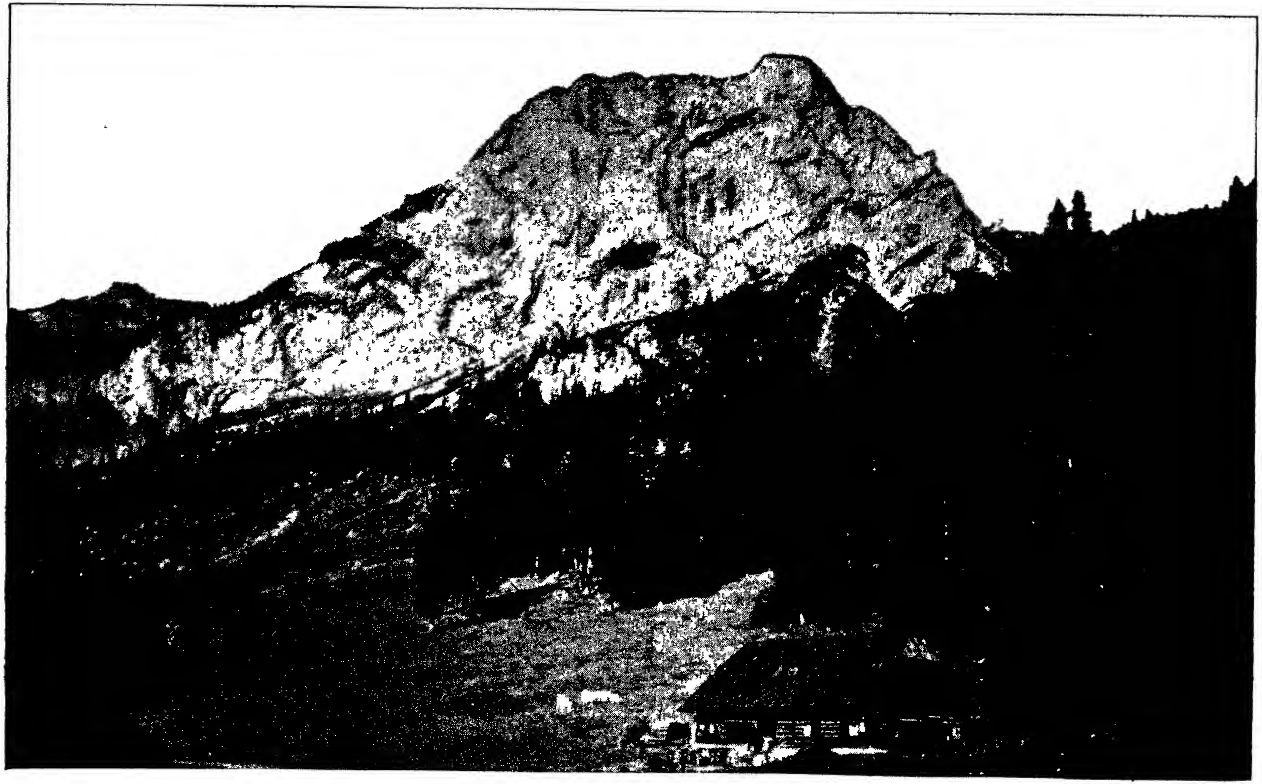
THE FRAUENMAUERHOHLE.

Eisenerz, in Eastern Tyrol, is a picturesquely situated little town. It is at the bottom of a great valley, with mountains all around it. Two of these are bare, gaunt limestone peaks, which are decidedly dolomitic in form and color. The sharpest of these is to the north. It is called the Pfaffenstein and is the beginning of the range culminating in the Frauenmauer. On a mountain to the east of the town, one sees the iron mines and works, whence the town takes its name "Ironore," and whence quantities of iron are taken out every year. The mines are said to have been in operation for over a thousand years, since about A. D. 800. After the ore is taken from the mine and roughly prepared, it is run down in small cars through a covered way to the railroad station to be shipped; and at certain times there is a seemingly endless procession of these cars, each bearing, besides its load of ore, a miner, with clothes and person entirely begrimed to the yellow-brown color of the iron.

As I walked out of the Eisenerz railroad station, an old man in Tyrolese costume asked me if I wanted a *träger* and a guide, so, while he was carrying my valise to the hotel, we came to terms. He was one of the

patented guides of the district and wore the large badge of the Austrian guides. If the size of the badge made the guide, one should be safe with Tyrolese, but for difficult excursions, it will not do to trust to a guide simply because he happens to be "patented"; that is, not if one values the safety of one's neck. Next morning, July the 9th, 1896, the old guide arrived betimes at the hotel and roused me by tapping on the wall below my window with his stick. We left at half past five o'clock. My companion, who should have known better, had not breakfasted, so by the time we reached the Gsoll Alp at a quarter-past seven, he was almost tired out. He wore the regulation black chamois knee breeches and a *gamsbart* in his hat. He picked many flowers en route, ostensibly because they were pretty; but in reality, I think, because it gave him the opportunity to recover his wind. He told me he was sixty-three years old, and he certainly went up hill with some difficulty, and for the first time in my life, I fairly succeeded in showing a clean pair of heels to a *patentirter führer* on a mountain side. At one place he found a large snail in the road. This he wrapped up in leaves and placed on a rock, and on our return he picked the leaves and snail up, and rammed the whole bundle into his pocket, informing me that it was excellent *Arznei*, although he did not mention for what complaint.

The road led up a wooded valley, in a sort of series of steps, bits of even ground interspersed by steeper ones, with the Pfaffenstein-Frauenmauer limestone peaks poking



THE FRAUENMAUER AND THE GSOLL ALP.

up their jagged summits on the left. The sky was clear at starting, except in the west, where clouds were forming, and these gradually overspread the whole sky, and finally turned to rain. Just before we reached the Gsoll Alp, we went by a huge snow avalanche, which had fallen in February and torn a lane clear through the pines, bringing down numbers of them with it. The remains of the avalanche were banked up on the side of the road, which was cut out, and many of the pines were still piled on and in the snow. Stopping ten minutes at the alp to allow my guide to recuperate on some bread and milk, we then crossed the pastures and pushed up a rather steep slope by a small path, at one place crossing the remains of another avalanche. We also came near having the attentions of a little bull which was screaming viciously. My guide said it was an extremely disagreeable beast, but he did not think it would attack him, as he always made a point of giving it bread when at the châlet. We reached the entrance of the cave at a quarter-past eight.

A man and a boy from Eisenerz, who had heard I was going to the cavern and who wished to profit by my guide, caught up with us here. They were much disappointed when I told them I should visit only the *Eiskammer*. They went into the cave at the same time that we did, and eventually we left them pushing up one of the side chambers, with only one torch in their possession. My guide said he thought they were risking their lives, as there were many holes they might

fall into, besides the probability of their finding themselves in total darkness. He told me that once, while in the cavern, he heard distant yells, and, going up the gallery whence they proceeded, found a man half dead, who said he had tried to come through the mountain by himself, had broken his lantern and had remained in the darkness an indefinite number of hours; a situation, the horror of which could not be realized by anyone who has not been underground without a light and felt the absolute blackness of a cavern.

The Frauenmauer is a limestone peak, 1828 meters in height, one of several forming a horseshoe round the Gsoll Alp. It presents on that side a sheer wall of rock, in which there are two holes close together, at an altitude of 1335 meters. These are the lower openings of the Frauenmauerhöhle, of which the higher and biggest one is used for an entrance. They are some thirty or forty meters from the base of the rock wall, and a flight of wooden steps leads up to the entrance opening, which is narrow and high. At the top of the steps, we stood in the mouth of the cave; and, going in four or five meters, saw the other opening to the left, below us. About five meters further, there was one small lump of ice, as big as a pumpkin, lying on the ground, but this may have been carried there from within. The cavern went nearly straight for some twenty-five meters from the entrance, rising all the time gently. Then came a steep little drop, of some four or five meters, in the rock floor, and here a small wooden staircase was

IN THE FRAUENMAUERHOHLE.

From a Photograph by A. Kurka.

placed. A gallery opened to the right and this was the cavern proper, which leads through the mountain. It rose considerably and contained no ice as far as we went, which was for some distance. The walking was bad, as the floor was covered with *geröll*, that is broken detritus.

Returning and continuing towards the freezing chamber, the floor of the cavern began to rise once more, continuing for some forty-five meters to its highest point, which is lower, however, than the top of the entrance, an important fact to notice. For, although the floor of the cave is considerably higher, at a distance of seventy meters within, than the level of the bottom of the entrance; still, that highest spot is below the level of the top of the entrance. This fact, and also the size of the gallery, unquestionably explains why the cold air can get in as far as it does. At this highest spot we found a considerable mass of ice, a couple of cartloads in bulk perhaps, which the guide said would melt away later in the summer. This was, perhaps, the remains of a fallen stalactite. This mass of ice is an interesting point in connection with the Frauenmauerhöhle, for it shows that ice in a cave sometimes forms, even if in small quantities, above the level of the base of the entrance. There seems no reason why it should not do so, provided there is the necessary water supply. Such ice would, however, suffer more, as soon as the outside air was over freezing point, than would ice which was below the level of the entrance. It would probably disappear early

in the year, unless the cave were in a latitude or at an altitude where snow remained in the open during most of the year.

From this highest point, the cave turns somewhat to the left, and the floor begins to slope downward, sinking gradually to some six meters below the level of the entrance. Ten meters or so from the highest point, we began to find icicles and fissure columns, and about twenty

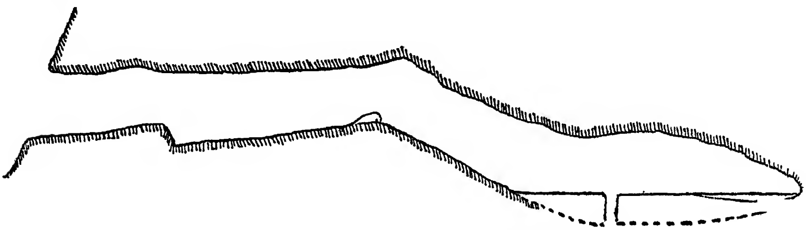


FIG 5 VERTICAL SECTION OF THE FRAUENMAUERHÖHLE

meters further, we reached an almost level ice floor, stretching across the entire width of the cave—some seven meters—and extending about fifty meters more to the end of the cave. In several places there was much frozen rime on the rock walls. There were also a number of columns and icicles, though none of any special beauty. I broke a piece off one of them, and the ice was transparent and free from prisms, showing that this column was probably of fairly recent origin. Letting a bit melt in my mouth, the water tasted pure and sweet.

In two places, there were *abgrunds*, that is, holes in the ice. One of these was a wide, deep hole on the left side of the cave, between the rock and the ice floor. The other was a great hole in the ice floor itself. As

ICE STALACTITE, FRAUENMAUERHOHLE. From a Photograph by A Kurka

the edges of both holes sloped sharply, it was impossible to get near enough to look into either, but I threw in lumps of ice, and from the sound should judge that the holes were about three meters deep. The hole in the ice floor seemed to be cut by drip, and I think they both carried off the drainage.

The ice floor was sloppy and thawing rapidly. At the furthest point we reached, within about fifteen meters from the end of the ice chamber, we were stopped by an accumulation of water lying on the ice. I poked into it with my ice axe and found it about twenty centimeters in depth. There was a crust of ice on top in places. The lake was cold, but I am sure the water was not freezing, as I held my hand in it at least a minute without pain. The guide assured me that in two weeks or so the lake would be completely frozen, provided there was some fine, warm weather; but, if there was rain, he said that it would not freeze. By this statement, he unintentionally explained, what he asserted was true, namely, that the cave froze harder in August than in July. The explanation of course is, that in fine, dry weather, water does not run into the cavern, and then the lake gradually drains off, leaving the ice floor free from water; and this the natives interpret to mean that the water has frozen up.

At the edge of the lake there was a fissure in the left hand rock wall, in which my companion assured me that a column would shortly form. I absolutely doubt this statement, as, if it were true, it would be contrary to everything I have seen; still, I wish I could have returned

in August, to verify the matter. I poked my torch up the fissure, also felt in with my hand. It was cold, and on the rocks inside there was much hoar frost, but I could neither see nor feel any ice mass, nor am I sure how far the fissure extended.

The air was still, damp and over freezing point throughout the *Eiskammer*, and all the signs showed that the cave was in a state of thaw. Although the rocks are limestone and scarcely blackened by smoke anywhere, yet as our torches did not give much light, the color impression was black and gray, like the Schafloch.

At the hotel the landlord confirmed in every particular the story of the cave freezing hardest in August or September. He had never been there himself, but stated that everyone said the same thing, and that many people had "broken their heads" trying to account for it. At eight o'clock in the evening, my guide came to let me know that the man and boy, whom we left trying to penetrate the cave, had just turned up after making all their relatives extremely anxious. They were nearly lost, and had in general an extremely uncomfortable time. It is scarcely to be wondered at that accidents occur in caves and on mountains when people, with neither knowledge nor proper preparation, go wandering off by themselves into the unknown.[4]

[4] On the evening of June 29th, 1897, I met at Hieflau three Viennese tourists who had come that day through the Frauenmauer. They found the lake on the ice floor of the *Eiskammer*, just as I had in 1896. They said also, moreover, that they found ice and icicles or ice columns in the main cave; unfortunately, they did not explain clearly in what part.

THE MILCHHAUSER OF SEELISBERG.

The summer of 1896, will long be remembered by Alpine climbers for the pitiless rain storm, which kept coming steadily down during the vacation months. It was in the midst of this that I arrived at Trieb, on the Lake of Lucerne, on the 6th of August, to see whether I could find the windholes which were reported near Seelisberg. At the landing place I found Herr J. M. Ziegler, the owner of the Hotel Bellevue at Seelisberg, who promptly secured a nice, blond bearded young fellow, a relative of his and his *knecht*, as a guide. It was pouring when we started, a proceeding which kept on during our entire excursion. We tramped up a narrow road, paved with great stones in the old Swiss fashion, and, as my guide truly said, awfully steep for horses.

Half an hour from the boat landing, took us to the first milkhouse, which belonged to Herr Ziegler. It was in a small patch of woods, and was placed against a cliff, where rocks had fallen down and formed a talus of broken detritus. The side walls of the house were built out from the cliff and roofed over, and the front wall had a doorway closed with a wooden door. At the back the detritus or *geröll* was built into a vertical, unplastered wall between most of the interstices of which, cool air came forth. Several of these interstices were fairly large holes of uncertain depth. It was a cool day and the air currents were only a little cooler than the temperature outside.

Another half an hour of uphill walking, partly on roads

and partly over soaking meadows, took us to Seelisberg, where we stopped at the house of the owner of the second milkhouse, to get the key. The owner could not go with us because he had damaged his foot, by wearing great wooden shoes or *sabots* armed with enormous spikes, while cutting grass on steep slopes. He was hospitable enough: unlike his dog, who was exceedingly anxious to attack us. The owner said—in the intervals of the dog's howls—that ice formed during the winter in the rear wall of his milkhouse and remained until about June. The milkhouse was in a little patch of woods against a small cliff, at the bottom of which were broken rocks. We had some difficulty in getting in, working for at least ten minutes at the lock, while drops of rainwater would occasionally drip into our coat collars. Just as I had given up hope, my companion succeeded in getting the key to turn. There were several pans, full of milk, placed to cool, and several barrels of potatoes; and, as at the first milkhouse, we found that the rear wall consisted simply of heaped up detritus built into a vertical position. Gentle air currents flowed from several large holes and from the cracks between the stones.

From here we went by a path through woods and over meadows down to the lake, coming to the shore some distance to the west of the steamboat landing. Everything was soaking wet, and as we proceeded, I felt my clothes getting wetter and my shoes absorbing water like sponges until, when we came to an overflowing brook, wading through seemed rather pleasant. There is one advantage

of getting thoroughly wet feet in the mountains: it makes crossing streams so much easier, as one does not delay, but simply steps right in.

The lower milkhouse was on the shore of the lake, near the house of a fisherman, whose wife opened the door for us. There was some milk in pans and several barrels of wine; and on a board were a number of *ferras* from the lake; the result of two days' catching in nets. This was the largest of the three milkhouses; although it did not have as many big holes in the rock wall as the others, but only the interstices between the blocks of rock, whence we could feel cool air flowing out. The woman said that the ice melted away by April or May, but that in winter the wine barrels were all covered with frost. She also said that the air coming from the clefts in summer was colder when the weather was warm, than when it was rainy. Doubtless the temperature of the draughts remains the same during the summer, but the air feels cooler to the hand when the outside air is hot.

A walk of another half hour, through more soaking wet grass, brought us back to the steamboat landing at Trieb, where I touched my guide's heart with the gift of a five franc piece, and had a talk with Herr Ziegler. He said that there were a number of places in the neighborhood whence cold air came forth during the summer from cracks in the rocks: that there were also other milkhouses, notably one at Tell's Platte, on the lake: and that the milkhouses were not generally used in winter, when the doors were left open, to allow the cold air to penetrate as much as possible

through the rocks behind. During the winter the draughts were reversed, and poured in instead of out of the openings, and Herr Ziegler thought that at that time the interior of the rock cracks became chilled, and that possibly ice formed in them which helped to chill the summer currents, when the draughts poured out from the holes.

THE GLACIÈRE DE LA GENOLLIÈRE.

On Tuesday, the 11th of August, 1896, a cool and rainy day, I left Geneva and went by train to Nyon, where I found at the station a little victoria, in which I drove up to Saint-Cergues. The road lay across the plain to the base of the slopes of the Jura, and then up these in long zigzags; it was admirably built and on the hill slopes passed the whole way through a beautiful thick forest, principally beeches and birches. At Saint-Cergues, I went to the Pension Capt, where the landlady soon found a guide in the shape of the gendarme of the district, a right good fellow, Amy Aimée Turrian by name. He was in uniform, with an army revolver in a holster at his belt. We then drove about half an hour beyond Saint-Cergues, the road rising but little, and the thick forest giving place to a more open wood of evergreens, with patches of pasturage. As a forest sanitarium, Saint-Cergues seems unsurpassed in the whole of Europe. The carriage turned up a little country road, which soon became too rough for driving, so we proceeded on foot for about another half hour, through pine woods and pastures, to the glacière. Turrian enlivened the way with an account of his life as a gendarme, of the long soli-

tary six hour patrols in the woods in winter, and of how he lay in ambush for poachers. He said he would not take long to fire on anyone resisting arrest, as that was *sérieux*.

The glacière is in the middle of a pasture, with several pine trees overhanging it. It is surrounded by a wall, built to prevent the cows from falling in. There are two pits, side by side and about three meters apart: they are some thirteen meters in depth, with a width of five or six meters. They open into one another at the bottom; the rock separating them, forming a natural bridge overhead. One of the pits is vertical on all sides. The other is vertical all around, except on the side furthest away from the natural bridge. Here the side of the pit is in the shape, so usual in glacières, of a steep slope. Down this slope we descended. It was slippery and muddy, owing to the recent heavy rains, and my ice axe proved invaluable and probably saved me some unpleasant falls. Under the bridge, the floor was covered with a mass of shattered limestone debris, among which there was neither ice nor snow; both of which my guide said he had found in abundance the preceding June. A little limestone cavern opened on one side below the bridge. A great, flat limestone slab formed a natural lintel, and, lighting our candles, we stooped down and passed under it into the cave, which was about the size of a room and in which we could just stand up. At the entrance and over most of the floor there was ice, in one place thirty or forty centimeters in depth, as I could see where a drip from

the roof had cut a hole. There were no signs of icicles or columns. My guide said he had never penetrated into this chamber, which he thought, on his earlier visit, was blocked with ice and snow. I did not see any limestone stalactites anywhere, and I am inclined to think that the low temperatures of glacières have a tendency to prevent their formation.

After our visit, we went to the Châlet de La Genollière close by, where there were some thirty cows and calves. The intelligent *berger* or manager said that most of the ice from the glacière was used for butter making during the hot weather; and that between the inroads thus made upon it and from other causes, the ice disappeared every year before autumn, but that it formed afresh every winter; pretty good evidence to show that the ice in this cave has nothing to do with a glacial period. He also stated that when he first entered the inner chamber in the spring there were four ice columns there.

The glacière de La Genollière is a clear exemplification of the theory that the cold of winter is the sole cause for the ice. The whole glacière is rather small and is fairly well protected against wind. Although snow cannot fall directly under the rock arch, yet I should imagine it drifts under, or after melting, runs in and refreezes. To the inner cave snow, as snow, could hardly reach; and the cavern is probably filled, like most cave glacières, from frozen drip. The inner cave is, therefore, a true cave glacière, while the outer pits and the bridge are something between a gorge and a cave. La Genollière should,

I think, be visited about the end of June, when the ice formations are certainly larger and more interesting than in August.

THE FRIEDRICHSTEINER OR GOTTSCHEER EISHÖHLE.

A little to the east of, and in about the same latitude as Trieste, is the small town of Gottschee, now reached by a branch railroad from Laibach. Gottschee is a German settlement almost in the centre of the district known as the Duchy of Krain, Austria, which is mainly inhabited in the north by Slavonians and in the south by Croatians. Gottschee lies directly at the western base of the Friedrichsteiner Gebirge, one of whose peaks is the Burgernock. On the eastern slopes of this mountain is situated the Friedrichsteiner or Gottscheer Eishöhle, at an altitude of about nine hundred meters.

On the 24th of June, 1897, I left Gottschee at half past six o'clock in the morning with Stefan Klenka, a nice little man. I had asked to have him come at six o'clock, but he did not turn up and I had to send for him. His excuse was, that tourists always ordered him for six o'clock, but when the time came, they were still in bed. He had taken a German officer and his wife to the cave the year before, and after keeping him waiting three hours, they started at nine o'clock. The result was that they did not get to the cave until two o'clock, and returned to Gottschee just at nightfall.

We reached the cave at half past eight o'clock. The steep and rough path went uphill through a fine forest,

which my guide said was *Urwald*, *i. e.*, primeval forest; and there were certainly some big trees and many fallen ones, and much underbrush. He assured me that bears were still plentiful in the neighborhood, and that Prince Auersperg, who owns the shooting, does not allow them to be killed, preferring to pay for any damage they may cause to the peasants' fields or for any cattle they may dine on, rather than to have these interesting animals exterminated from his woods. He also said that there was a two meter snowfall in Gottschee in winter: a sufficient quantity to account for the glacières. At one place on the road we stopped before a small crack in the rocks, and Klenka dropped in some small stones, which we could hear strike two or three times a long distance below. There is surely an unexplored cavern at this spot.

The Friedrichsteiner Eishöhle is a large pit cave, well lighted by daylight. It is sheltered from any winds by the great trees which grow all around it and even over the rock roof. A long, steep slope leads straight into the pit and from the top the ice floor is in full sight. On both sides of the slope the rocks are almost sheer. Over the bottom of the slope the rock roof projects at a great height. The sides of the cave rise perpendicularly at least forty meters, and in fact, the cave suggests an unfinished tunnel set on end.

Some years ago, the *Deutschen und Oesterreichischen Alpen Verein* built a wooden staircase, in a series of zigzags, on the slope. This staircase should have been cleared off earlier in the year, but, of course, the matter

was neglected. Down these steps we descended until they became covered with snow, and lower down with hard ice. All this was winter's snow which fell directly on to the slope and gradually melted and froze again, so this was really a miniature glacier. It was not subterranean ice at all. We cut down the snow, but had to stop when we came to the ice, as it would have involved a couple of hours at least of the hardest kind of step cutting; and this my guide did not care to undertake, especially as he was nearly killed on this slope the week before. He had reached, with some tourists from Trieste, a place above that where we stopped, when he slipped and fell down the slope, shooting clear across the cave, where he remained until ropes were procured, and he was dragged out. He afterwards showed me the numerous cuts and bruises he had received on his perilous glissade.

We had to stop also for another reason. I had unwisely brought as wrap, a thick overcoat reaching to the knees, and this was such an impediment on the icy staircase, that I took it off, and soon began to feel long shivers creeping down my spine. This question of extra clothing for glacière exploration is hard to arrange. One must guard against most trying changes of temperature. For, on entering a big glacière, the heat of a July day without, will, at a distance of only a few meters, give place to the cold of a January day within, and nothing could be better devised than a big glacière to lay the seeds of rheumatism. It is difficult to plan a garb suitable to meet all the varying conditions, but the

dress must be cool and warm, and light enough to permit free motion. The clothes I have found most practical are a thin waistcoat and thick trousers, and two short sack coats, one of them a heavy winter one. The coats should button at the throat, and it is well to place straps round the bottom of the trousers. Thick kid gloves should always be worn in caves, to save cutting the hands on rocks or ice in the darkness, and hobnails may prevent some unpleasant slips.

From the point where we stopped, some ten meters away from the ice floor, the largest portion of the cave was visible. The finest object was a big ice curtain or *vorhang*, as my guide called it, which, from a height of five or six meters, flowed down from fissures to the ice floor, and which covered the rocks on the eastern side. Under one point of this curtain, Klenka said that there was a deep hole in the ice. Smaller fissure columns also streamed from the rear wall to the ice floor. The ice floor itself was flat, of an ochre greenish tinge, and was covered with broken ice fragments. We could not see the western portion of the cavern, as the rocks jutted out in a sort of corner. Klenka said that there were several small pyramids there; a large one which he spoke of as the *Altar;* and a small ice slope, plastered on the side rocks.

The sides of the cave were of a dark gray limestone rock, and from the top of the slope they assumed a decidedly bluish tone, and I am inclined to think that there was already—we were there from eight-thirty A. M.

until ten A. M.—a faint mist in the cavern. This is the most interesting phenomenon connected with the Friedrichsteiner Eishöhle. The cavern faces due south, and about midday, in clear weather, the sun shines directly into it, causing a mist or cloud to form in the cave on warm days; a mute witness that evaporation is connected with the melting, not with the forming, of the ice. The air at every point seemed still.

On my return to Gottschee, I called on one of the professors of the K. K. Gymnasium, and he told me many interesting facts about the surrounding country. Among other things he said that no traces of a glacial period or indeed of glaciers were found in the Krain; and as this district is particularly rich in glacières, this fact is a strong proof against the glacial period theory. He assured me also that many bears still existed in the neighborhood; that one family was known to inhabit the woods round the Friedrichsteiner Eishöhle, and that he had often seen bear tracks on his own shooting, some ten kilometers to the south.

THE SUCHENREUTHER EISLOCH.

On the 25th of June, 1897, I left Gottschee at six-thirty A. M. in an *einspänner*, and drove thirteen kilometers southward, over a good road, albeit hilly in places, to Mrauen, which we reached in about two hours. The weather was exceedingly hot. I took Klenka along, as he spoke German, and he entertained me on the drive by telling me that there were many poisonous snakes in

the country, of which the *kreuzotters* or vipers were the worst, and that three or four persons were bitten every year.

Mrauen is in Croatia, and I could see a slight difference in the people and their dress from those of Gottschee. From Mrauen, the landlord of the *Gasthaus Post*, Josef Sirar, led us to the Grosses Eisloch. This is sometimes spoken of as the Eisloch bei Skrill, but as it lies in a patch of woods below the village of Suchenreuth, the Suchenreuther Eisloch seems the correct name. At least that was what Sirar called it. It took us about an hour on foot from Mrauen to get into the woods. On the way we met two guards in uniform, carrying Männlicher carbines with fixed bayonets, and it was agreeable to feel that the strong arm of the Austrian government extended over this semi-wild land. In the woods, following Sirar's able guidance, we took a short cut—always a mistake—and were lost temporarily in a maze of bushes and brambles, in which I thought of the *kreuzotters*. After that, Sirar at first could not find the cave and had to hunt around for it, while I sat on a stone and waited impatiently.

At the cave a rather steep slope of wet mud, covered with dead leaves, led down through a rock arch. Sirar had to cut several steps in the mud with his hatchet, or we should probably have sat down suddenly. The archway opened into a moderately large cavern, which was about twenty meters deep, almost round and some fifteen meters in diameter. The slope continued

right across the cave, and on some parts of it were logs of wood and much débris. On the wall hung a few limestone stalactites. In the roof of the cave was a great hole, and under this was a big cone of old winter snow, which had become icy in its consistency, and on which there was much dirt and many leaves. The tem-

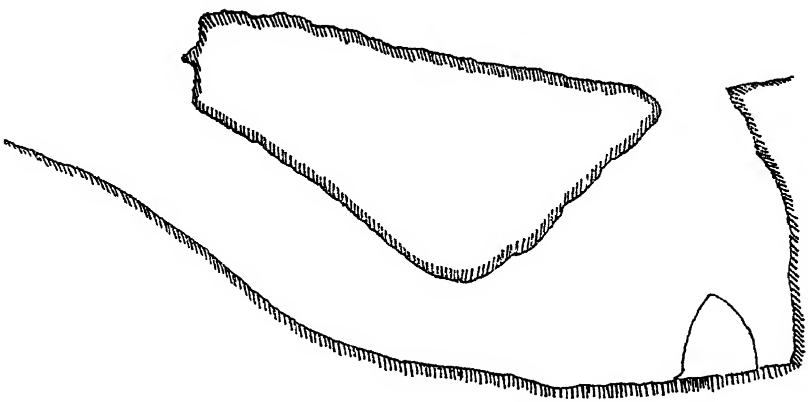


FIG. 6 VERTICAL SECTION OF THE SUCHENREUTHER EISLOCH

perature in the cave was several degrees above freezing point, and there was no ice hanging anywhere. Sirar said that when the weather got hotter, the ice would come; but as he said also, that he had been only once before in the cave, some ten years ago, his opinion was not worth much. Both men said that the preceding winter was unusually warm.

THE NIXLOCH.

Near Hallthurm in Bavaria, a railroad station between Reichenhall and Berchtesgaden, is a well known congeries of windholes, called the Nixloch. I visited it

on Friday, July the 2d, 1897, with a railroad employee, whom I found at the peasants' *gasthaus*.

The Nixloch is ten minutes distant in the forest, on the slopes of the Untersberg. It is among a mass of big limestone blocks, and close by are the remains of the walls of an old castle or fortification. The Nixloch descends from the entrance for about two meters nearly sheer, and there is just room to get through. As I sat within the outside edge of the mouth of the cave, the smoke of my cigar was slowly carried downward into it.

Dropping down through the hole, we found ourselves in a small cavern formed of rough limestone blocks overhead and underfoot. It is possible to go still further down and my companion said that formerly it was possible to go through the cave and come out at a lower opening; this exit, however, was destroyed when the railroad was built. The draught, as tested by the flame of a candle, was still drawing in some seven or eight meters from the entrance. There is a second cavity immediately next to the entrance, and at the bottom of these holes, the inward draught was so violent as to blow the candle out. The thermometer outside in the shade was 28° C.; inside the cave, where the draught was still perceptible, it was about 20° C. Within the cave I noticed two large, dark brown spiders.

On returning to the *gasthaus*, I had a talk with some peasants who were dining there, and they told me that it was warm in winter in the Nixloch, and that ice never formed there.

THE DORNBURG.

If one draws a line northeast from Coblentz and another northwest from Frankfort-on-the-Main, they will intersect nearly at the Dornburg. The railroad from Frankfort goes, via Limburg and Hadamar, to Frickhofen and Wilsenroth, from either of which villages the ice formations of the Dornburg are easily reached on foot in half an hour.

I arrived at Wilsenroth on the 26th of July, 1897, and soon found an old forester, who said he had lived in the neighborhood for over fifty years, to show me the way. The Dornburg is a low hill, perhaps a hundred meters high and a kilometer long. It is basaltic and covered with sparse woods. The forester said that on top were the remains of the foundations of an old castle, and that this was possibly the origin of the name Dornburg. We circled round the eastern base of the hill for some ten minutes, when we came to a little depression, filled with basalt debris, among which were several small holes, out of which came currents of cool air.

Ten minutes further in the woods, we arrived at the *Dornburg Restauration* and then almost immediately at the glacière. It is at the bottom of a talus of broken basaltic rocks and has been much affected by the agency of man. In it are two *eislöcher* or *stollen*, as the forester called them. These are little artificial pits or cellars, dug into the talus. They are side by side, opening about southeast, and each is about one and a half meters wide,

three meters long, and two meters high. The sides are built up with wooden posts and overhead is a thick roof of logs strewn with dirt. The day was cool and at the mouth of each *eisloch*, a faint outward current of air was discernible at nine-thirty A. M. I could not find any currents coming into the *eislöcher*. Inside it was cold and damp, and evidently thawing. There was a good heap of ice in each *eisloch;* it was clear, and I could detect no trace of prisms.

By much questioning, I dug out something of the history of these *stollen* from the forester. Formerly the ice was found at this spot, among the boulders at the base of the slope. But the people gradually took many of these basaltic blocks away, to break up for road making, and then the ice diminished. About 1870, a brewery, since burnt, was built at the Dornburg and the brewer had these *stollen* built, a sort of semi-natural, semi-artificial ice house. Every winter, the present owner of the *stollen* throws a quantity of snow into them, and this helps materially in forming the mass of ice.

Just below the restaurant there is a spring, which was said to be extremely cold, but there was nothing icy nor apparently unusual about it.

Under the restaurant itself is an interesting cellar. It was closed by wooden doors. First there was a passage way which turned steadily to the right, and which we descended by some ten steps. This was about two meters wide and was full of beer bottles and vegetables. On the left of the passage was a large double chamber where

meat is kept. At eleven-thirty A. M. a faint draught blew down the passage and into the hall, the outside door being then open. The double hall was perhaps six meters each way, and I could detect no air currents coming into it at any place, except from the passage way. Both passage and halls were, as far as I could see, entirely built over with masonry. There was no ice and the temperature was some 7° or 8° above freezing point.

The daughter of the proprietor of the restaurant said that ice began to form in the cellar in February and that it lasted generally until October; but that this year it was destroyed early because the masonry was repaired, although it was still possible to skate in the cellar as late as March. In the beginning of winter the cellar was warm, and as she expressed it, *der Keller schwitzt dann*, which I suppose means that the walls are damp. She also said that it was a *naturlicher Keller*, and I am inclined to think that it was a natural glacière, converted into a cellar.

This visit to the Dornburg gave me many new ideas about classifying glacières, especially in relation to the movements of air. I was long puzzled by the German terms, *Eishöhlen* and *Windröhren;* and it suddenly struck me, at the Dornburg, that this terminology is incorrect, when used as a classification of glacières. The presence or absence of strong, apparent draughts, cannot be considered as a test as to whether a place is or is not a glacière; the presence of ice, for at least part of the year, alone makes a glacière, and this it does whether

there are or are not draughts. It seems to me more than ever clear, however, that it all depends on the movements of air, as to whether ice forms in a cave. If the movements of air take the cold air of winter into a cave, then and then only—provided there is also a water supply—do we have ice. I am now inclined to think that caves, as far as their temperatures are concerned, should be classified into caves containing ice, cold caves, ordinary normal caves, and hot caves, without reference to the movements of air.

THE GLACIÈRE DE SAINT-GEORGES

From Rolle, on the north shore of the Lake of Geneva, an excellent carriage road leads in two hours and a half to Saint-Georges in the Jura. At first the way goes steeply uphill and passes through many vineyards, and afterwards it crosses level fields to Gimel, then rises through woods to Saint-Georges. On arriving there on the afternoon of August 3d, 1897, I found the street filled with evergreens, and long benches and tables; the débris of a *fête de tir*, which had lasted for two days, with dancing and banquets and, I suspect, much *vin du pays*.

When I got down stairs at six o'clock next morning, all the people of the inn were sound asleep recovering from the effects of the *fête*, and instead of their calling me, I had to call them. Finally I succeeded in getting breakfast and then started in company with a first rate fellow, named Aymon Émery.

LA GLACIÈRE DE SAINT-GEORGES.

From a Photograph by E Truand

We walked up through woods, in about an hour and a half, to the Glacière de Saint-Georges, which lies at an altitude of 1287 meters in the midst of the forest. There are two holes close together. One of these descends vertically and is partly roofed over with logs on which is rigged a pulley. Émery, who was the *entrepreneur* of the glacière, which means that he attended to getting out the ice, told me that they pulled the ice up through this vertical hole, making a noose with a rope round each block.

The other and shallower opening ended in a rock floor, which was reached by a short ladder. To the right was an arch, under which the rock terminated as a floor and descended vertically, forming the wall of the cave. On this wall two ladders, spliced at the end into one long ladder, were placed in a nearly vertical position. I tied the end of my rope round my waist, and got a workman, who had come to cut ice, to pay out the rope to me, while I went down.

The cave is rather long and narrow, perhaps twenty-five meters by twelve meters, and the limestone roof forms an arched descending curve overhead. I could not see any limestone stalactites; neither were there any ice stalactites or stalagmites in the cave, but a good part of the wall, against which the long ladder was placed, was covered by an ice curtain. It was thin and had evidently been damaged by the ice cutters or I think it would have covered the entire lower portion of the wall.

The base of the long ladder rested on an ice floor

which filled the bottom of the cave, and which would probably have been level if it had not been cut out here and there in places, leaving many holes. A good many broken ice fragments lay on the floor and in some of the holes were pools of water. Some of the floor ice

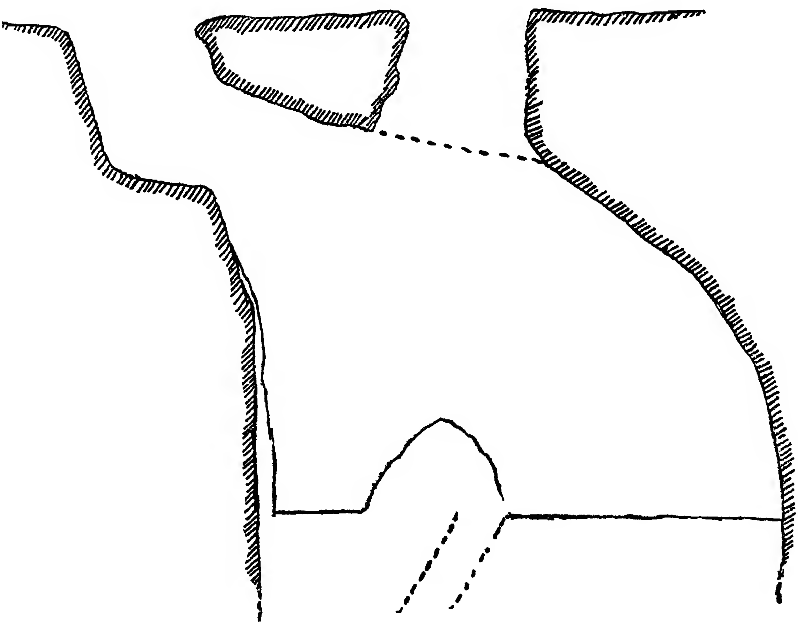


FIG. 7 VERTICAL SECTION OF THE GLACIÈRE DE SAINT-GEORGES.

was exceedingly prismatic in character, and I was able to flake it off or break it easily with my hands into prisms.

Under the vertical shaft, which is at one end of the cave, was a mass of winter's snow which had fallen through the opening. Under this snow was a deep hole, which I believe was the drain hole of the glacière before the ice floor was cut away to a level below its mouth.

Into this hole I threw lumps of ice and heard them go bumping down for three or four seconds.

The atmosphere was not uncomfortable, although the temperature was about 7° C. The air did not feel damp, and seemed almost still, but standing on the ice floor nearly under the vertical hole, I found that the smoke from my cigar ascended rapidly, and it seemed as if there were a rising air current, which sucked up the smoke.

Saint-Georges is a fine cavern and well worth visiting. Émery said that the ice was not cut out for eight years preceding the summer of 1897, and that for several years it was not possible to go down at all, as there were no ladders, until he put in the two we utilized.[5] All the natives of Saint-Georges believed that the ice was a summer formation and that it was warm in the cave in winter.

THE GLACIÈRE DU PRÉ DE SAINT-LIVRES.

From the Glacière de Saint-Georges, Émery and I pushed on through the woods to the Pré de Saint-Livres. In several places we came on the tracks of deer, and my guide told me he had killed eleven roe during the last hunting season. He said also that an attempt is being

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[5] In the illustration of the Glacière de Saint-Georges, the opening to the left is the vertical pit, through which the ice is taken out: underneath it, is the heap of winter snow. The man in the upper part of the picture is standing on the rock shelf at the base of the upper ladder and at the top of the lower ladder. To the right of the lower ladder near the bottom, a bit of the ice curtain is visible.

made to introduce the red deer into the Jura, and that the experiment seemed to be meeting with success. We kept to the crest of the ridge along wood paths, and, as the day was fortunately cool and cloudy, we were able to walk fast and reached the Pré de Saint-Livres in two hours. At a spot called La Foiraudaz we met the workmen coming down with a cartload of ice, which they were taking to Bière. Some of this ice was extremely prismatic.

The Pré de Saint-Livres is a big mountain pasture or meadow, surrounded with hills covered with pine trees. In the middle of it is the Châlet de Saint-Livres, round which numerous cows and calves were congregated and where a small shepherd gave us some milk. The châlet is not one of the old picturesque Swiss châlets with great stones on the roof to keep it from being blown away by the wind, but a strongly built single storied stone structure, which looks extremely modern among the green hills.

The glacière lies close to the châlet, on the southern side of the meadows, just on the edge of the woods, and is surrounded with trees. It is at an altitude of 1362 meters and faces nearly due north. To prevent the cattle from falling in, it is enclosed with a stone wall, except in front, where there is a fence formed of an abattis of pine trees. The cave belongs to the pit variety, and the pit is a big one. As you stand at the top, you can look down to the end of the glacière. The rocks are vertical all round the pit, and in front there is a small rock

shelf, one-third of the way down, which divides the rock wall into two long drops. Against each of these was a rickety ladder, so we fixed the end of my rope to the pine trees of the fence, and hung on to it while we climbed down. The base of the lower and longer ladder rested on a mass of snow. This was the beginning of a long snow slope which gradually turned to ice and filled the cave. The cave itself, measuring along the snow slope, is some forty meters long and some ten to fifteen meters wide, and is entirely lighted by daylight.

The snow and ice slope fell in a series of small waves, and the upper portion was rather dirty. On the right hand the workmen had fixed a rope as a handrail, and all the way down had cut a staircase in the ice, so that the descent was not difficult. Some of the ice was sloppy. The ice mass did not abut entirely against the end of the cave, but left an open space between the ice and the rock, some three or four meters wide and some four or five meters deep. Here the workmen had been getting their ice, and had cut into the ice mass for several meters, forming a little tunnel.

There were no ice cones nor stalactites, neither did I see any limestone stalactites. Much of the ice was prismatic; in fact, together with that at Saint-Georges, it was the most strongly prismatic I have seen. I can perhaps best describe it, by saying that it was brittle in texture, as I could break up small lumps in my hands. There was more prismatic ice at Saint-Livrés, however, than at Saint-Georges. The air in the cave was still

and decidedly damp; and the temperature was several degrees above freezing point. The day, however, was almost windless, and I would not assert that movements of air, due to the wind, might not sometimes take place in the pit.

The Glacière du Pré de Saint-Livres is one of those caves which may be looked on as a transitional form between gorges containing ice and caves containing ice. The winter snow falls into the mouth of the pit, and is the chief foundation of the ice mass. It would be interesting to make a series of observations in this cave to see whether there was anything like glacier motion. Émery, of his own accord, expressed the opinion that much of the ice here was due to the winter snows; in fact, he thought that it was all due to it, and that it gradually descended into the cave and turned, little by little, into ice. He told me that some years ago a cow was found by the workmen, frozen into the ice, at a depth of four meters; the flesh was perfectly preserved, and was eaten. I asked him if he had ever seen insects in either cave, and he said he had not.

From the glacière we walked back to the village of Saint-Georges. On asking my guide how much I owed him, he said he received four francs for a *journée*, so I gave him six francs, and we parted the best of friends.

GLACIER ICE CAVE IN THE FEE GLACIER.

During a rather protracted stay at Saas-Fee in Switzerland, I visited the glacier ice cave of the Fee Glacier on

the 15th and 16th of August, 1897, both cool and rainy days. It is about half an hour's walk from the hotel to the ice cave, which is in the snout of the Fee glacier, below the Eggfluh. A considerable stream issued from the cave. On nearing the opening, a strong cold air current poured out above the stream. At the front edge of the ice, the height of the ice roof in the centre was perhaps twelve meters and the width fifteen meters. Around the edge, the roof formed an almost perfect curve. The ice walls contracted in a regular manner within, and the cave became narrower and lower, and suggested an enormous funnel cut in half, into which you looked from the larger end. The cave also grew gradually darker, and the darkness prevented seeing further than to a depth of some fifteen meters. In the ice walls, just inside the entrance, were several crevasses, of the ordinary blue-green color. They followed nearly the same curve as the roof, but did not go through to the outside. There were no icicles. The ice was faintly stratified in places, and at the outer edge was brittle. It did not break into the long narrow prisms of the ice at Saint-Georges and the Pré de Saint-Livres, but rather into small lumps with facets, of all sorts of shapes. It was evidently unsafe to penetrate under the ice roof, for while I stood in front of the cave, a large lump broke off from the roof and fell with a clatter among a lot of other ice fragments already on the moraine floor. In two places there was a steady rain of drops from the roof, showing that the ice was melting.

This is perhaps the glacier cave in Switzerland which is easiest to visit, and my inspection intensified my belief in what I consider the correct explanation of some of the phenomena in glacières. The suggestion was that as soon as the temperature gets above freezing point in a glacier ice cave, the only process is that of destruction of the ice, which seems to be also the case with glacières.

LA GRAND CAVE DE MONTARQUIS.

My brother and I left Cluses, in Savoie, a railroad station on the line between Geneva and Chamonix, at two o'clock on the afternoon of the 22d of August, 1897, and drove up in two hours and a half to Pralong du Reposoir, a distance of eleven kilometers. The road is a *route nationale*, fine and broad, with parapets in many places. After passing Scionzier, it mounts gradually, passing through a tremendous wild gorge, cut by the waters and heavily clad with firs. We reached Pralong at four-thirty, and stopped at a primitive inn, still in process of construction, and tenanted only by blue-bloused peasants, who, as it was Sunday night, sat up late, drinking and making a heathenish noise they mistook for singing. I talked to some of these men, and they all insisted that there was no ice at the Grand Cave in winter, but that it came in summer. *Plus il fait chaud, plus ça gèle*, they said. One man explained the formation of the ice in an original way, and with an intelligence far above that of the average peasant. He considered that it was due to air currents, and thought that in winter

the snow stopped up the holes in the rocks, through which the currents came; but that when the snow melted, the draughts could work, and that then they formed the ice.

The weather was abominable next morning, the clouds lying along and dripping into the valley; but the inn was so awful that we decided to try to reach the cave. We had a nice little blue-bloused peasant for a guide, Sylvain Jean Cotterlaz by name. We went first for about an hour on foot towards Le Grand Bornant on a fair road, to an alp called La Salle. This was surrounded by a herd of cows, some of whom seemed interested in our party. It now began to rain fiercely, and except for my brother's perseverance, I should certainly have given in. A fair path led up steep grass slopes into the clouds covering the Mont Bargy. Each of us had his umbrella raised, and the ascent was slippery and uninspiring. An hour took us to two deserted huts, the Alpe Montarquis, and half an hour beyond, we came to the caves; by which time we were thoroughly soaked.

The caves are on Mont Bargy, at the base of a limestone precipice, which, I think, faces nearly north. There are three caves close together. The lowest, or Petite Cave de Montarquis, Cotterlaz said is also called La Cave des Faux-Monayeurs; as according to a, probably untrue, tradition, it was once used by counterfeiters. Above this is a small rock pocket, accessible down an easy slope. We went in and found that there was no ice and indeed scarcely any water in it.

The Grand—not Grande—Cave is a little higher up,

and as we came to it, several sheep, which had taken refuge in the mouth from the storm, hastily skipped away, evidently distrusting our intentions. The altitude of the cave is said to be 2078 meters. The entrance must face about north east; it is elliptical in shape, about fifteen meters wide, and six meters high, and is badly sheltered against the wind. The cave is of moderate size, about sixty meters in length and forty-five meters in width, and the average height of the roof is not over four or five meters. A gentle slope leads downwards. Many blocks

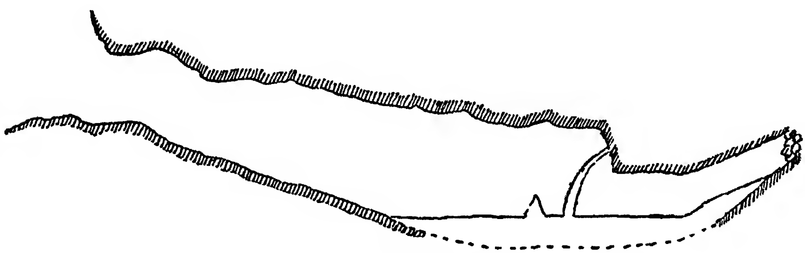

FIG. 8 VERTICAL SECTION OF GRAND CAVE DE MONTARQUIS.

of rock in the front part had bits of moss growing on them, and some of the mud there was of a dull purple color, as if some dark madder was mixed with it. There was a red streak in the right hand wall, probably caused by iron. I observed no limestone stalactites nor stalagmites in the cave, the main body of which was well lighted throughout by daylight.

The ice was in the shape of a nearly level floor, about twelve meters long and eight meters wide: the shape was irregular, and the ice so smooth that it was hard to stand up. The rocks in the rear overhung the ice

floor at one spot; and here, there streamed from a fissure to the ice floor an ice column, some three meters high, whose base was fully two meters distant from the rock wall. Near this column was a tiny ice cone, which evidently had been bigger. Cotterlaz seemed impressed with the fact that there was only one column in the cave, as he said that in June, there would have been many columns and a larger and deeper ice floor. The ice was sloppy in places, with several small hollows cut by the drip and containing water. In one place there was a tiny runnel filled with water, but there was no current. There was a good deal of drip all through the cave, and in fact in one or two places we might have kept on holding up our umbrellas with advantage. I hacked at several pieces of ice, but none of it was prismatic.

At the rear of the cave, the ice ran, in a tongue, up the entrance of an ascending fissure in the rocks. My brother cut here six or seven steps in the ice; and he found them difficult to make, as the ice was hard and thin, and not in a melting state. Above the ice tongue we clambered up the rocks of the fissure some four or five meters further, finding there some lumps of ice which were not melting. At this spot we were almost in darkness. A lighted match burned steadily, so that there was evidently not much draught, but the smoke gradually descended, showing a slight downward current. This was the coldest, as well as the furthest point of the cave we could reach, and we there heard a tiny waterfall trickling within the fissure, although we could not see it.

By this time we were all chilled to the bone, so, abandoning the idea of entering the Petite Cave, we retreated down the sopping wet, slippery grass slopes to Pralong, and then immediately walked all the way to Cluses to avoid taking cold. The Grand Cave was the most fatiguing trip I ever made after glacières, but the circumstances were rather unusual.

THE FREEZING WELL OF OWEGO.

On Thursday, June 23d, 1898, I went to Owego, in Tioga County, New York. Inquiries at the Lehigh Valley railroad station and at the chief hotel failed to elicit any information about a freezing well; and in fact, I soon found that the existence of such a thing was a blank to the rising generation. So I called on an old resident of Owego, who told me that he knew of the well in question and that it was filled up with stones many years ago; but that he remembered that, when he was a boy, it used to freeze, and that it was spoken of as the deep well or freezing well. I then walked up to the site of the well, which is about one and a half kilometers to the northwest from the centre of Owego and about one kilometer from the Susquehanna River. It is directly in the middle of the highway, and nothing is now visible but a heap of stones.

Near by was the house of a Mr. Preston, who told me he was born in 1816, and had lived all his life at this spot. He said that the well was about twenty-eight meters deep,

and that it went first through a layer of sand and then through a layer of gravel. He had more than once been down the well and had seen the sides covered with ice. A bucket sent down for water would sometimes come up with ice on the sides. Whether the water at the bottom ever froze, no one knew, for the ice caked and filled up the bore at about two-thirds of the way down and became so thick, that as Mr. Preston put it, "it was just like hammering on an anvil to try to break it." He also stated that another well was dug about one hundred meters further down the road, and that originally this sometimes had a little ice on the sides. Of late years however, it was covered over with a wooden top and since then no ice was known to form. I could obtain no information about any other wells in the neighborhood ever showing similar peculiarities.

THE ICY GLEN, NEAR STOCKBRIDGE.

The Icy Glen is situated on Bear Mountain, about one kilometer from Stockbridge, Massachusetts. It is in the midst of fine woods and there are many big trees in it. The bottom of the glen is full of rocks and boulders, among which there is a rough path. I was told that ice remained over there much longer than anywhere else in the neighborhood, sometimes as late as May. On the 3d of July, 1898, I not only found no traces of ice or snow, but the temperatures under the boulders showed nothing abnormal. To make up for this, however, there were legions of mosquitoes.

FREEZING MARBLE CAVE, NEAR MANCHESTER.

Near Manchester, Vermont, there is a little cave,[6] which is noteworthy, in that it is in a marble formation. It is known as Skinner's Cave, because it was owned for many years by Mr. Mark Skinner. It lies in Skinner's Hollow, some five or six kilometers from the centre of Manchester, at the base of the eastern slope of Mount Equinox, of the Taghconic Range of the Green Mountains.

The cave is on the property of Mr. N. M. Canfield, who, on learning the object of my visit, on the 5th of July, 1898, with true native American courtesy, walked up to it with me. The last two kilometers were over a rough logging road, which towards the end was steep and covered with many broken logs. I could not have found the cave alone, as it was so surrounded with bushes, that the entrance was invisible until we actually reached it. It is in a gorge of Mount Equinox, in the midst of a beautiful forest, which effectually cuts off any wind. The cave faces nearly north and can scarcely ever, if indeed at any time, be reached by the rays of the sun. The moment we got into the entrance, we found the chilly, damp, summer atmosphere of true glacière caves. The rocks were brown and mossy on the outside, but Mr. Canfield called my attention to the fact that

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[6] My attention was called to this cave, by Messrs. John Ritchie, Jr., of Boston, and Byerly Hart of Philadelphia, who visited it some years ago. Mr. Ritchie's opinion is that it is simply a refrigerator.

they were marble, and on his knocking off a small piece, a section of pure white marble was exposed. In no other instance have I heard of a marble cave in connection with ice. There were scarcely any cracks or crevices in the rock.

The cave goes down with a steep slope from the entrance, much in the shape of a tunnel, for some ten meters. The slope was covered with slippery mud and decayed leaves, and at the bottom expanded into a little chamber, in which lay a mass of wet, compact snow, some two by three meters. It was evident that the snow was simply drifted in during the winter, and was in too large a mass and too well protected to melt easily, and there could be no question but that this place was purely a refrigerator. The air was tranquil throughout and there were no draughts. On the same day, a good breeze was blowing in the Manchester Valley.

THE FREEZING WELL OF BRANDON.

The Freezing Well of Brandon is situated on the western or southwestern outskirts of the village of Brandon, Vermont, not far from the railroad station. I visited it on the 7th of July, 1898. The well was protected by a wooden cover. On raising this, a faint stream of cool air seemed to issue forth; but this was probably only imagination. The sides, as far down as one could see, were built in with rather large blocks of stone without cement. At the bottom water was visible and there were no signs of ice. We drew up some water in a

bucket, and although it was cool there was nothing icy about it. I twice lowered a thermometer nearly to the water and each time after ten minutes it registered only 13° C. There was certainly nothing abnormal in this temperature, in fact it was strictly normal and my thermometer showed conclusively by its actions that it could not have been near any ice mass. The people at the house, however, assured me that a month before there was ice in the well.

Afterwards I called on Mr. C. O. Luce, the owner of the well. He stated that it was eleven and a half meters deep to the bottom, that it was dug in 1858, and that the ground through which it goes was found frozen at a depth of about four and a half meters. Here there is a stratum of gravel and this is where the freezing occurs. Mr. Luce thought that the water was under the ice, that is, that the water came up from the bottom. He said also that the well usually froze solid in winter; but, that as this winter was an open one, there was less ice this year than usual. He thought that there was less ice anyway now than in former years, partly because of the cover which was put over the well, and which keeps out some of the cold; and partly because a neighboring gravel hillock, called the Hogback, was a good deal cut away, and this in some way affects the supply of cold in the gravel. He added that the sandy soil round Brandon does not as a rule freeze to a greater depth than two meters each winter. The house built beside the well was said to be comfortable in winter.

There seems no doubt that this is another refrigerator. The cold water of the winter snows percolates into the gravel mass and refreezes, and, owing to the bad conductive quality of the material, the gravel remains frozen later than the soil elsewhere in the neighborhood. The fact that the well went through a frozen gravel stratum when dug, proves that it is not alone the air that sinks into the well itself, which makes the ice. The fact that the well freezes on the whole less than formerly, apparently partly owing to the digging up of some of the gravel close by, goes to prove the same thing. The fact that the well generally freezes solid every winter, shows that although some of the gravel mass possibly remains frozen all the time, much of the ice is renewed each year. This is especially important as proving that the ice found in gravel deposits is due to the cold of winter and not to a glacial period, although, of course, no one could say for how long a time the ice was forming and melting; and this process might date back to the time of the formation of the gravel mass.

I could learn nothing of any similar place near Brandon, except that Mr. Luce said that in an old abandoned silver mine in the neighborhood, he had once seen ice during hot weather.

FREEZING TALUS ON LOWER AUSABLE POND.

On the eastern side of Lower Ausable Pond, Essex County, New York, at the foot of Mount Sébille or Colvin, there is a talus of great Laurentian boulders, which fell from the mountain and lie piled up on the edge of the

lake. Among these boulders, at a distance of about five hundred meters from the southern end of the lake, there are spaces, several of which might be called caves, although they are really hollows between the boulders. On the 12th of July, 1898, I visited this spot with Mr. Edward I. H. Howell of Philadelphia. From several of the rock cracks we found a draught of air flowing strongly out, as tested by the smoke of a cigar. The air was distinctly icy and there could be no question that there was a considerable quantity of ice among the rocks to produce the temperature.

In three places we found masses of ice. One of these hollows was small, and the other two were much larger. One of the latter was almost round in shape, and perhaps three meters in diameter; with a little snow near the mouth and with plenty of ice at the bottom. The other was a long descending crack between two boulders which joined overhead, and with the bottom filled by a long, narrow slope of ice, perhaps seventy-five centimeters in width and six meters in length, set at an angle of about thirty-five degrees. The ice was hard and non-prismatic.

The cold air affects a large area of land around the boulders. Mr. Howell called my attention to the flowers of the bunch-berry, which he said were at least two weeks behind those on the surrounding mountains. The same was true of *oxalis*, a pretty white flower, of which we found several beds in full bloom.

Mr. Howell went to this talus, on the 4th of July

previous, with Mr. Niles, President of the Appalachian Mountain Club, on which occasion they found plenty of snow near the entrance of the larger hollow. Mr. Howell, indeed, has repeatedly visited this place, and always found ice, which must, therefore, be looked on as perennial. At all times also he has felt cold draughts flowing out; sometimes they were so strong as to lower the temperature over the lake to a distance of thirty meters or more: on hot days he has seen occasionally a misty cloud form on the lake in front of the boulders. Mr. Howell considers that the draughts so affect the surrounding air, that an artificial climate is produced, and it is owing to this that spring flowers bloom late in July and sometimes in August. Another fact well known to him, is that in hot weather, the spot in front of the boulders is the best in the whole lake to catch trout, as they always congregate in the coldest water. The Adirondack guides use these ice retaining hollows, which they call ice-caves, as refrigerators for their provisions and game in hot weather: they say that the ice is formed in winter and remains over during the summer, as it is so well sheltered.

FREEZING TALUS OF THE GIANT OF THE VALLEY.

On the indications of Mr. Otis, chief guide of the Adirondack Reserve, I explored with Mr. C. Lamb, a guide from Keene Valley, the southern base of the Giant of the Valley Mountain, Essex County, New York, on the 14th of July, 1898. A road runs from Keene Heights to Port Henry, through the gap between the south base

of the Giant of the Valley and the north base of Round Mountain, and passes close to a small lake called Chapel Pond. Some three hundred meters west of this lake, we left the road and struck north, across the brook, into the thick, mossy woods. After perhaps one hundred meters, we came to a talus of great boulders of Laurentian rock, with the cliffs of the Giant, whence the boulders had fallen, rising steeply above. We found ice under several of them, although never in any quantity. The thermometer, after an exposure of fifteen minutes in one of these little hollows, registered 6° C., although not more than one meter from where the sunshine fell on the moss. In the shade of a tree one meter distant from the same hollow it registered 26° C.; a difference of 20° C. at a distance of only two meters.

Perhaps one kilometer east of Chapel Pond, there is a place, where the bases of the mountains come much nearer together, which bears the name of "The Narrows." Here we crossed the brook again, and, after some fifteen or twenty meters of scrambling through rough woods, reached once more the talus of the Giant, composed of tremendous boulders. Among these we found ice in many places and this time in large quantities. Within one boulder cave we found an ice slab some four meters in length, by two meters in width, and one meter in thickness. This was pure, hard and non-prismatic ice, and was evidently not formed of compressed snow: in fact snow could not have drifted in under the boulder. We broke off a large piece of ice and took it back to Saint Hubert's Inn, and it

melted rather slowly. From the mouth of this cave an icy draught issued, and, as it struck the warmer air outside, a slight mist was formed. Mr. Lamb said that from the road itself he had sometimes seen mist rising from this talus. Further explorations of the talus of the Giant would probably reveal ice in many other places than those we examined.[7]

Mr. Lamb told me of two other places in the Adirondacks, where he found ice in similar boulder formations. One was in the talus of Mount Wallface in Indian Pass, between Mounts Wallface and McIntyre. The other was in the talus of Mount McIntyre in Avalanche Pass, between Mounts McIntyre and Colden. At the latter place, he found it near the trail going round the lake in the pass.

THE ICE GULCH, RANDOLPH.

The Randolph Ice Gulch is situated in Randolph Township, New Hampshire, about eight kilometers from Randolph Station, on the Boston and Maine Railroad.[8] I visited it on August 11th, 1898. At the Mount Crescent House, I found a guide in the person of Mr. Charles E.

[7] Mr. E. I. H. Howell examined several times, in 1899, the talus of the Giant of the Valley. He found ice in many places ; also cold air currents blowing out. At one spot, there is a spring which flows all through the summer, and the water is so cold, that its temperature is little above that of melting ice. Mr. Howell found, as at Ausable Pond, spring flowers growing in mid-summer among the rocks of the talus.

[8] I first heard of the Ice Gulch from Mr. John Ritchie, Jr., of Boston. Some years ago in the middle of July, he found ice plentiful in the second chamber. He thought the Gulch only a refrigerator.

Lowe, Jr. The excursion took us about six hours. The trail was a rough bush path, cut by the Appalachian Mountain Club, and which had not been cleaned out that year. It was a cloudy but hot day and this, combined with the badness of the road, made the walk fatiguing.

The Gulch lies between Crescent and Black Mountains. The altitude of the upper end of the Gulch is something over eight hundred meters, that of the lower end about six hundred meters. It is some fifteen hundred meters long, and averages perhaps one hundred meters in width at the top, and only a few meters at the bottom. The depth may be about seventy-five meters and the sides are steep, in some places sheer. The bottom is a mass of broken, fallen rocks, with a good many trees growing among them. There are several steps, so to speak, in the Gulch, which are called chambers, although the term seems rather meaningless. Promenading through the bottom of the Gulch was fraught with difficulty, because the rocks were placed in most unsuitable positions for human progression, and my hands were certainly as useful to me as my feet in preserving equilibrium. We found ice in one or two places, but not in any great quantity. In one spot it was overlaid by water. My guide said that there was less ice than the year before. A large piece which we broke off, and which furnished us with a cooling morsel of frozen fluid, was full of air bubbles. It was not prismatic ice, and was certainly unusual in formation. It crunched up under the teeth and, although it did not look like solidified snow, yet, judging

from its position among the boulders, it was doubtless formed from the melting and refreezing of snow.[9] My guide said he had heard that fresh ice began to form sometimes in September. The Gulch is well protected against wind, and I detected no draughts among the rocks. Except in the immediate vicinity of the ice, the temperature was not abnormally low.

On returning to the Mount Crescent House, I had a talk with Mr. Charles E. Lowe, Sr., who told me that Alpine plants, like those which grow on Mount Washington and Mount Adams, are found in the Gulch; but that they do not exist on the neighboring Black and Crescent Mountains. He said also that ice was present in more than one place in King's Ravine, and that it was always there.

FREEZING BOULDER TALUS AT RUMNEY.

About three kilometers south of Rumney, New Hampshire, there is a hill called Bald Mountain, which, about three hundred meters west of the carriage road from Rumney to Plymouth, descends as a big cliff, with an exposure facing nearly southeast. At the base of this cliff, there is a talus[10] which I visited on the 27th of

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[9] On the 17th of February, 1899, four days after the greatest snow storm in Philadelphia in many years, I noticed that the snow on my roof solidified slowly into a mass of ice which contained a good many air-bubbles. It strikingly resembled the ice of the Ice Gulch, only that it was more solid and did not have more than half as many air-bubbles.

[10] Mr. John Ritchie, Jr., wrote me about this place, where he had found ice plentiful some years ago in August, within two or three meters from the outside: he considered it only a refrigerator.

August, 1898, with the Sheriff of Rumney, Mr. Learned. He said he had found plenty of ice there on the 18th of August, 1897, but he doubted whether there would be any left this year, on account of the hot weather. Effectively a careful hunt failed to reveal any ice, although the talus was just the kind of place where it might have been expected, as the boulders were piled one over the other and in one or two places there were considerable hollows. The temperatures were normal, and there were no draughts. The talus is exposed to the sun, and only moderately sheltered against wind by a scrub forest. But there can be no doubt, that ice lingers there long after it has disappeared from every other spot in the neighborhood, and it seems as if our not finding any, is another proof that it is the heat of summer which melts it away.

ICE FORMATIONS AND WINDHOLES AT WATERTOWN.

At Watertown, New York, on the south side of the Black River, in the town itself, are some natural cracks or crevices in the limestone rocks. They are only a short distance from the New York Central Railroad station. The cracks enter the northern side of the railroad embankment, pass under the railroad tracks, and extend some distance back. In front of them are four cellars, used for storing beer kegs. The lessor, Mr. Ehrlicher, obligingly had the cellars opened for me, on the 12th of September, 1898. There was neither ice nor draughts in the cellars, and the temperature was normal. Mr. Ehrlicher said that in the spring there was ice in the

THE BLUFF AT DECORAH.

From a Photograph by Mr A F Kovarık

cracks, but that it had all melted away as the result of the hot summer.

About four kilometers west of Watertown, on the south bank of the Black River, is the picnic ground of Glen Park, which is reached by trolley. The manager of the restaurant walked around the park with me. In one spot is a hollow or glen at the base of a small, much cracked limestone cliff, which has a northern exposure. The manager said that snow and ice usually lies in this place until June, not only among the broken rocks, but even in the open. Sometimes ice remains among the boulders all summer, but only near the front of the boulders, and by pushing in, one soon gets beyond it: we found none, a fact showing once more the effect of the unusually warm summer. On hot days, draughts issue from between the boulders, but as the day was cool, we did not notice any. The spot is well sheltered against the wind by a number of trees; and the shape of the hollow reminded me of the glen in front of the Eishöhle bei Roth.

Not one hundred meters from this hollow, is a little limestone cave, closed by a wooden door, which excludes any cold air in winter. The cave is lighted by electric lights, and is a narrow, crooked, descending fissure, a *ganghöhle*, where the marks of water action are plainly visible. At the bottom a little stream, evidently the active agent in forming the cave, ran through the fissured limestone. In the stream a large toad or frog was swimming about. There was nothing icy about the cave or the water, and the

temperature was normal. Ice was never known to form in the cave. These two places, so close together, are an interesting confirmation that it is only where the outside cold can get in, that we find subterranean ice.

THE FREEZING CAVE AND FREEZING WELLS OF DECORAH.

Near Decorah, Iowa, is a freezing cavern, which is more frequently referred to in cave literature than is generally the case. I visited it on Friday, September the 30th, 1898, with an old English resident of Decorah, Mr. W. D. Selby-Hill. The cave is situated about one kilometer to the northward of Decorah, on the north bank of the Upper Iowa River, at the base of a bluff. It is some thirty to forty meters above the stream, and faces southward. It looks like a fault or fissure in the rocks, with the sides meeting a few meters overhead. It is a true cave, but probably in an early stage of formation, for there are no apparent traces of water action, nor any stalagmites nor stalactites. The absence of the latter may, however, be due to the fact that it is a periodic glacière. The rock is a white limestone, rich in fossils. The cave is some two to three meters in width and is rather winding, with a short arm or pocket branching out on the west side. The main cave runs back some thirty meters from the entrance. In one place it is necessary to stoop, to get past some overhanging rock slabs. By candle light, we went to the rear of the cave, and found it warm, dry, and free from ice. There were no draughts, possibly because the day was cool.

ENTRANCE OF THE CAVE OF DECORAH

From a Photograph by Mr. A F Kovarik.

I looked in vain for *tubular fissures*, or indeed any fissures, through which *water might freeze by pressure in its descent*, as the believers in the capillary theory say it does. Nothing of the kind existed, and I wrote in my note-book: "Writing on the very spot about which this theory was started, I feel justified in asserting that the theory amounts to absolutely nothing and is entirely incorrect."

Mr. Hill told me that there were two wells in the southern portion of Decorah Township, where ice was found in summer. I visited them both, but found no ice, and the temperatures normal. Mr. Hill said that one of the wells was dug about thirty years ago, and that the workman told him that the ground which he went through was frozen; and that at one place he struck an opening, from which came so strong a current of icy air, that it was hard to keep at work.

I talked to several persons afterwards. *Inter alia*, they told me that the bluff was a great place for rattlesnakes, sometimes big ones. They admitted also generally that they were puzzled about the formation of ice in the cave. Some claimed that the ice formed in summer—the old story once more. I met, however, Mr. Alois F. Kovarik of the Decorah Institute, who had made a series of regular observations for over a year and found that the ice begins to form about the end of March and beginning of April, and is at its maximum towards the beginning of June. Mr. Kovarik also told me, that he had found ice in one of the wells in the beginning of August.

This was an especially satisfactory trip to me, for it did away, once for all, with any possible belief that there was any basis of fact for the capillary theory. It also seems to me important to find that the ice of these freezing wells melts in summer. For it shows that their ice is due to the same causes as those which form the ice in the cave, and is another proof against the validity of the glacial period theory.

FREEZING ROCK TALUS ON SPRUCE CREEK.

On Spruce Creek, Huntingdon County, Pennsylvania, about four kilometers north of the Pennsylvania Railroad depot, is an ice bearing talus, known locally as the Ice Holes or Ice Caves. I visited this spot, on October the 5th, 1898, with Mr. Benner, of Spruce Creek. We walked up the pretty valley along the old Pittsburgh turnpike, at one place finding some papaw trees, whose fruit had a horrible sickening taste; then we crossed Spruce Creek by a footbridge and followed the other bank back for some five hundred meters, until we were nearly opposite the old Colerain Forge, which is located in a piece of land called by the curious name of Africa. About half way from the bridge we smelt a strange odor, which my companion thought came from a copperhead or rattlesnake: we did not investigate.

The freezing talus is situated at the foot of Tussey Mountain: it is big, and is composed of small sandstone (?) rock débris. The talus is at least thirty meters high and one hundred and twenty meters long. As I

LOCUS GLACIALIS—CAVE OF DECORAH.

From a Photograph by Mr A F Kovarik

stood at the bottom, I was reminded strongly of the talus at the Dornburg. At the base were a number of small pits, evidently dug by man. From the interstices between the rocks, icy cold draughts issued in some places, and there was no doubt that there was plenty of ice beneath the stones. In one place we thought we could see ice, and I poked at the white substance with my stick, but I am not positive that it was ice. All over the talus, the temperature was strikingly colder than a few meters away, and in the pits we could see our breaths distinctly. Although I am not much of a botanist, yet it seemed to me that the flora immediately near the talus was somewhat different in character from that of the surrounding country.

Mr. Benner told me that he saw, three or four weeks before, plenty of ice in the pits; that they were made by farmers who formerly came to this spot to get ice; and that parties occasionally picnic here in the summer and make ice cream. He stated also that he saw, some years ago, a small cave or hole containing ice near Mapleton, Pennsylvania, but that it was destroyed by quarrying the rock away.

FREEZING GORGE NEAR ELLENVILLE.

On Sunday, October the 9th, 1898, with a young man from Ellenville, I visited the well known Ellenville Gorge, in the Shawangunk Range, Ulster County, New York. We left the hotel at eight-forty A. M. and reached the gorge, known locally as the Ice Cave, at ten-five A. M.

It is about four kilometers northeast from Ellenville. The path rises steadily uphill and is of the roughest description; it is covered with loose stones, and looks as if it might become the bed of a mountain brook in wet weather.

I call this place a gorge, instead of a cave, because it is uncovered at the top, but probably originally it was covered. It is shaped like a pit cave minus a roof, and it reminded me of the Friedrichsteiner Eishöhle, and the Glacières de Saint-Georges and du Pré de Saint-Livres. It is entered by a long slope from the western end, the gorge turning northward further back. I estimated its width, at the bottom at some five to seven meters, at the top at some three to four meters; its length at some thirty meters and the deepest point we reached, at some twenty meters below the surface. These are guesses, however. In one place, a great rock slab overhangs the gorge. At nearly the lowest point of the rock floor, there is a hole which extends perpendicularly downwards some five or ten meters more; this opening is partly blocked up with fallen masses of rock which would make a further descent perilous. The north end of the gorge is also filled up with a mass of great broken rocks; in fact, the whole place is out of repair, as the rocks are cracked and creviced on both sides to a great extent. The rock is friable and seems to be all breaking up, or rather down, and I think there is some danger from falling stones, although I did not see any fall. There is a good deal of moss on the sides of the gorge, and on some ledges small evergreens are

GORGE AT ELLENVILLE.

From a Photograph by Mr. Davis

growing. The gorge is sheltered thoroughly from winds by its formation and position, and somewhat by the scrub forest surrounding it. There are several long, deep crevices a few meters further up the mountain side, and I think one of them is an extension of the main gorge.

We found no ice. It generally lasts till about the beginning of September; and Professor Angelo Heilprin, and Miss Julia L. Lewis, of Philadelphia, have found plenty of it in July and August. But the ice had evidently now been gone for some time, for the temperature at the bottom of the gorge was about 11° C. at ten-thirty A. M. This was but little colder than the temperature outside, which at ten-fifteen A. M. was 14° C.

On returning to Ellenville, I learnt that there was another somewhat similar smaller gorge, some eight kilometers away, at a place called Sam's Point. This, however, is said to retain only snow, while in the Ellenville gorge much ice is sometimes formed, and icicles a couple of meters long are said to hang on the sides of the cliffs. The proprietor of the hotel told me he had heard of a cave which contained ice not far from Albany, at a place called Carlisle, on the Delaware and Hudson Railroad.

FREEZING CAVE AND WINDHOLES NEAR FARRANDSVILLE.

I arrived at Farrandsville, Clinton County, Pennsylvania, early on Tuesday morning, October the 11th, 1898, and found a boy, who worked in a brick mill, as guide to

the caves.[11] After emptying a small, flat bottomed boat of the water of which it was half full, we rowed across the Susquehanna River; then we walked up the road, along the river bank, for a couple of hundred meters, and struck up the so-called path to the caves. Although the whole of the mountain side was at the disposal of the road maker, no better plan seems to have suggested itself than to make the track go straight up. This saved making zigzags, yet the result is that the path is steep, and as it is rocky and slippery, it is hard travelling without bootnails or alpenstock.

As we went up, I noticed, in one or two places, cold draughts issuing from crevices in the rocks. We soon came to a hollow under a rock, where there were a number of cracks and crevices: the boy spoke of it as the lower cave. It is some sixty meters above the Susquehanna River and cold draughts flowed from the cracks, although we saw no ice. The cave was about twenty meters

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[11] I learned of this cave from Mr. Eugene F. McCabe, of Renovo, Pennsylvania. Mr. McCabe took out large pieces of ice from it in the month of August. On December 23d, 1896, he found no ice inside the cave, but a hoar frost covered the rocks; the temperature outside was —5.6°; inside —4.5°: the day was clear and there was no breeze; several matches lighted in the cave were almost instantly blown out by a current of air coming from crevices in the rocks.

Mr. Ira C. Chatham, postmaster at Farrandsville, wrote to me on the 19th of October, 1898, as follows: "Your paper on Ice Caves [Journal of the Franklin Institute, March, 1897] at pp. 177 and 178 describes the Farrandsville Cave as near as is possible, as the ice forms in the spring from the snow melting and dropping through the rocks into the cave, and the rocks face directly north as stated."

higher up. One could crawl into it for a couple of meters, and all round it the rocks are somewhat creviced; in fact, I think there are a good many cracks in the entire hill. There was no ice in sight in this hole, but a strong, cold draught poured from it. After an exposure of fifteen minutes the thermometer registered 6° C.; while outside, in the shade, it stood at 15° C. This decidedly sub-normal temperature proved unmistakably, in my opinion, the presence of ice a little further than we could see in. Both holes face about north and are sheltered, by their position and by the sparse forest which covers the ridge, against all winds except those from the north.

I talked to the postmaster and the railroad agent at Farrandsville on my return, and they stated that there was no ice in the hole in winter, but that it formed about April and remained over until towards September, showing that the cave is a normal glacière on a small scale.

GLACIÈRES NEAR SUMMIT.

In the search for coal, the mountains of the Appalachian Chain between the little town of Summit, and the neighboring village of Coaldale, Carbon County, Pennsylvania, were mined and tunneled in every direction. Owing to the caving in of some of these mines, depressions formed in certain places along the ridge in the upper surface of the ground, and in two of these hollows natural refrigerators occur. These were brought to my notice by Mr. C. J. Nicholson of Philadelphia, and I visited them on

May the 5th, 1899, in company with two coal miners of Summit.

Starting from Summit, we passed across some rough ground under which there was a mine on fire; and the miners showed me the tops of two pipes sticking out of the ground, from which issued a smoke or steam, too hot to hold the hand in more than a few seconds. Going beyond through brushwood, for a couple of hundred meters, we came to the first glacière, which was also the nearest to Summit. It faced almost due north and looked as if it was formerly the entrance to a mine. It was fairly big, and my companions assured me that, until within about a year, ice was always found in it. Recently, however, part of the rock roof fell in, blocking up the entrance with a mass of débris and making it unsafe to venture in. Formerly parties of tourists constantly visited this place, after coming over the Switchback, but this is no longer done and there has been some talk of cleaning away the broken rocks and making the glacière accessible. The men also said that occasionally people living in the neighborhood had dug out the ice for their own use.

The other glacière was a short distance further, in the direction of Coaldale. It is in a pit, which may have been the mouth of a disused shaft or only a depression resulting from a cave-in. A scrubby forest, which surrounds the hollow, acts as a windbrake. A rather steep slope leads down into the pit, and at the end passes under the wall of rock of the opposite side for a short distance, forming a small cave, which faces almost due

south and whose floor is choked up with broken rock fragments. At the bottom of the slope we found some snow, and among the boulders a good deal of snow-ice as well as several long icicles hanging from the rocks. All the ice and snow lay on the north side of the rocks, or

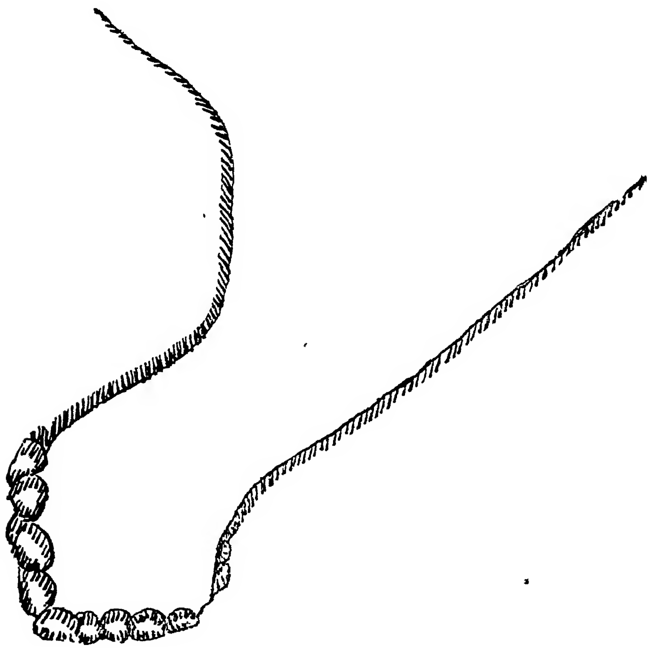

FIG. 9. VERTICAL SECTION OF PIT NEAR SUMMIT.

underneath them, so that it was in shady places where the sun could not reach it. The temperature was not at all uncomfortable, although somewhat cool and damp.

There was nothing in either glacière, to show that the ice was formed from any other cause than the drifting in, and melting and refreezing of the winter's snow; and my

impression is that the ice in the second glacière could not last through the summer.

THE SNOW HOLE NEAR WILLIAMSTOWN.

The Snow Hole near Williamstown (Massachusetts) is situated near the northern end of the Petersburgh Mountain of the Taghconic Range; it is slightly below the watershed on the Williamstown side, at an altitude of about seven hundred meters. The Snow Hole is in the State of New York, near the boundary between New York and Massachusetts. It is a long two hours' drive from Williamstown, the last four kilometers or so, over an exceedingly steep and rough road, which is, in fact, nothing but an old logging road, and the worst I ever drove over except the road to Démenyfálva.

I visited the Snow Hole with my brother on Friday, September the 29th, 1899. It is surrounded by a dense forest, mainly of recent growth, which thoroughly shelters it from all winds. In shape and appearance it resembles the Gorge at Ellenville, except that it is smaller: its location on the ridge is not unlike that of the Friedrichsteiner Eishöhle. It is a narrow crack—or cave minus a roof—about fifteen meters long, six to seven meters deep and from two to five meters wide. It faces nearly north, and the bottom is in perpetual shadow. From the northern end, a gentle slope leads to the rear. The slope was a good deal blocked up by a big tree with large branches, which had fallen directly into the fissure. There was some moss or greenish mould on the rocks in

places, and at the rear end of the slope there were some fissures in the rocks, into which one might perhaps have crawled a little farther, which formed a tiny cave. There was also a similar incipient cave at the northern end. I could not detect any draughts issuing from these rock fissures, and the air throughout was still, although the wind was blowing hard on the ridge. The rocks were moist in places and the air damp, but there was neither snow nor ice and the temperatures were normal. The driver told me that he had found plenty of snow in the base of the gorge some years ago in July; and he said that he had always heard that snow was found in the Snow Hole all the year round. All the conditions of the place, the shape of the fissure, and its sheltered northern exposition, are favorable to the retention of ice and snow, and it is not surprising that they remain over every spring.

ICY GULF NEAR GREAT BARRINGTON.

The Icy Gulf or Icy Glen is some eight kilometers from Great Barrington, Massachusetts. I have not been in it, but was told in October, 1899, by the farmers living near by, that after snowy winters, ice remains over through July. It must be similar to the Icy Glen at Stockbridge.

THE ICE BED OF WALLINGFORD.

The Ice Bed of Wallingford is situated about three kilometers to the east of Wallingford, Vermont. A drive of half an hour, over the Mount Holly and Hearburrow

roads, takes the visitor to the entrance of a rough wood path, which, at a distance of three or four hundred meters, leads to the Ice Bed. This is a huge talus, at the base of the White Rock Mountain, whose cliffs rise steeply overhead for some three or four hundred meters. The talus, which was doubtless formed by a great slide at some distant date, consists of granite boulders, some of which are big ones. The ice-bearing portion may be some thirty or forty meters high vertically. It lies in a sort of gully or rock basin, and at the top is about thirty meters broad, tapering to a point at the bottom. The talus faces southward, and during a good part of the day the sun shines full upon it. A thin forest fringes the sides and grows round the bottom, but this can afford but little protection from the winds, especially to those from the south.

I visited this place on the 5th of October, 1899. There was a distinct drop in temperature as we neared the base of the talus, and a cool air drew gently down over the rocks. I think slight draughts issued from some of the crevices; but of this I am not sure. The temperature was sub-normal, about 8°, but hardly low enough to prove the presence of ice, although we could see our breaths distinctly. We looked carefully under a number of the boulders, but neither ice nor snow was visible. I was assured that ice was abundant there in the past July and August, and I should think it had melted away only shortly before my visit. My impression is, that this is a periodic glacière.

CAVES NEAR WILLIAMSTOWN.

On the eastern slope of the Petersburgh Mountain of the Taghconic Range in Massachusetts, at a good deal lower altitude than the Williamstown Snow Hole and about southeast of it are some caverns, which are but little known. A five or six kilometer drive from Williamstown takes the visitor to the base of the mountain, whence a rather steep ascent of about a kilometer and a half brings him to the caves, which are in the midst of a dense, scrub forest.

The caves were first entered, and possibly discovered, by Mr. W. F. Williams, of Williamstown, when a boy. Since then, he has visited them many times and explored them a good deal. They do not appear to have any name as yet, and it would seem only fitting to christen them after their explorer: the Williams Caves.

There are several unimportant holes in the immediate neighborhood of the two main caves. The latter lie side by side. The rock formation is the same as that of the Snow Hole, a dark gray slate with a few veins of quartz, and they are due also evidently to the same geological causes. It would seem as though the mountain had tended to open or crack at these spots and fallen apart. This seems probable, because wherever there is a projection on one side of the cracks, there is a corresponding hollow in the opposite side. After this, water action has come, and erosion and corrosion have worn out and carried away earthy matter, and slowly deepened and

widened the fissures. The remarkable point in connection with the main caves, however, is that one is a normal cave and the other a periodic glacière.

I went with Mr. Williams to these caves on the 6th of October, 1899, and partially explored the glacière. On the way up, just as we left the carriage road, a fine, three-year-old buck, in his winter coat, came bounding out of the forest; on seeing us he stopped, and after taking a good look, quietly trotted off into the bushes.

The glacière is rather peculiar in shape and may be described as two storied. A long slope, set at an angle of some forty degrees, and covered with mud and dead leaves, leads down into the crack, which is from one to three meters in width. The first half of the slope is open to the sky; the last half is covered by the rock roof, and is a real cave. In this the floor is horizontal, the place forming a little chamber in which the daylight has almost vanished. At the exact summit of the slope a big tree grew most conveniently; and we tied to this one end of a twenty-meter Austrian Alpine Club rope, and by holding fast to it, and kneeling or sitting down in the mud in two or three places, the descent was easy enough. It was rather difficult to scramble up the slope again, however.

In the floor of the little chamber there are two holes, and, stepping over these, we stood at the rear end, about eighteen meters distant from the beginning of the slope. My companion now set some birchbark on fire and dropped it into the innermost hole, and we laid down in

turn, flat on the rock floor, and craned our necks through the hole. Mr. Williams thought he could see ice below us. I looked down after him and found that I was looking into a lower chamber whose sides were invisible. The floor was some three meters below vertically, and on this the birchbark was burning brightly. I think I saw

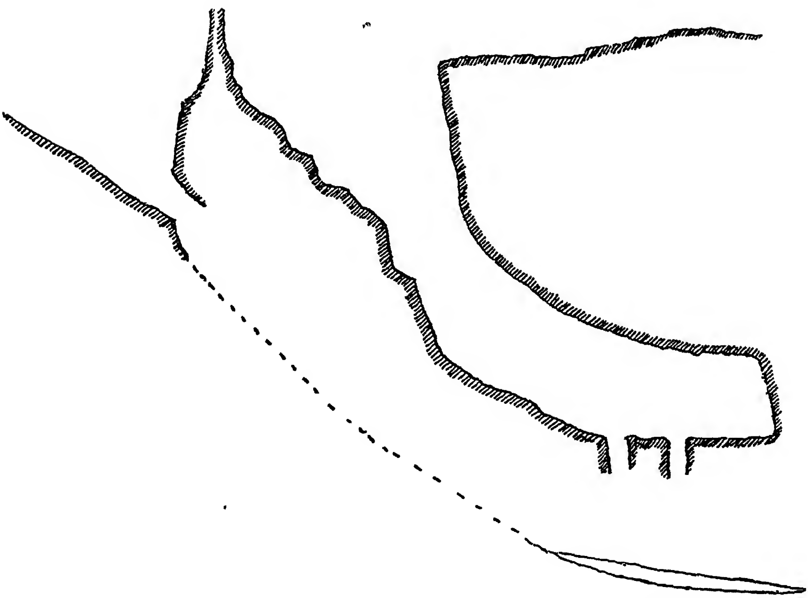

FIG. 10 VERTICAL SECTION OF FREEZING CAVE NEAR WILLIAMSTOWN.

some ice, but I could not be sure, as there was too much smoke to see distinctly. My companion offered to go down through the hole and get some ice; a proposition I promptly vetoed, as had anything gone wrong, I could not possibly have given him any assistance, as there was no extra rope. Mr. Williams told me that he went down several times before in July or August, and always found

ice on the slanting floor. He said he did not know how far this lower chamber extended, nor the length of the ice floor. One thing which makes me hesitate to think that we saw ice was, that the temperature of the chamber where we were was not at all icy; but probably—I had forgotten my thermometer—nearly normal.

When we stood once more by the tree at the top of the slope, the mouth of another cave was visible about two meters below us. Mr. Williams said it had never looked more than a little crack before, and that the opening was much bigger than at his last visit. It was directly under the slope by which we descended and it vanished into darkness. Its direction led straight towards the lower chamber, and it almost surely leads to it. It seems thus that there are two hollows, one directly above the other; and that the lower one is a glacière, while the upper one is not. The cold air of winter would naturally sink into the lower chamber, and the spring thaws would furnish plenty of drip, so that this place seems to answer every requirement of a cave glacière.

But the most interesting fact about these caves is that, while the shallower one is a glacière, the bigger and deeper one is not. This is situated about ten meters north of the glacière and the direction of the entrance is about the same. Mr. Williams has found snow and ice in May in the entrance pit as far as the daylight goes, but none beyond. I am inclined to think that the explanation of this is the fact that the cave is a *gang-höhle* or tunnel cave. Mr. Williams described it as a

narrow passage with chambers, and at least a hundred meters long, and fifty meters in depth below the surface. The cold air sinks in a certain distance, but as the passage is narrow and long, and too winding for any strong draughts, the cold air which enters is soon neutralized by the supply of warmer air within and by contact with the rocks. I cannot help thinking that it is by some such explanation that we must hope to solve the problem of why certain caves are glacières and others in the immediate neighborhood normal caves; and the caves near Williamstown are exceptional in presenting the problem so patently.

PART II.

THE CAUSES OF SUBTERRANEAN ICE.

THE CAUSES OF SUBTERRANEAN ICE.

I.

Terminology.—Ice enduring the entire year is found, in temperate latitudes, in a variety of forms and in several different kinds of places. In some cases it is entirely above the surface of the earth; in others it is entirely beneath the surface of the earth. These are the extremes, and between them there are certain intermediate forms. The perennial ice above ground of temperate regions has gradually become known in English by the French word *glacier*, but strange to say, there is no term in use in English which accurately describes the perennial ice formations which are partially or completely underground. Thus the term "ice cave" is applied to a rock cavern containing ice, and the term "ice gorge" to a rock gorge containing ice. Both terms are misleading, because the character of the contents is mentioned before the nature of the geological formation. We say correctly enough "limestone cave" or "lava cave" and, in my opinion, we should apply the term "ice cave" in a similar manner to the hollows in the ice at the lower end of glaciers, whence the glacier waters make their exit. These are really "ice caves," that is caves with

sides and roof made of ice. Another trouble of the term "ice cave," as applied to rock formations containing ice, is that it is not generic: not only is it incorrect, but also it is not comprehensive. It does not apply to mines, tunnels, wells, gullies, boulder taluses, or underground ice sheets. If "ice cave" is used, except in its true sense of glacier ice cave, it seems at least as though it should be so only for real caves which retain ice, as opposed to taluses and wells. Curiously enough, the Germans are just as inaccurate as ourselves, for their terms *eishöhle* and *eisloch* are absolute translations of our "ice cave" and "ice hole." Indeed, there is no doubt that some of the incorrect notions about subterranean ice formations, are due to the inaccuracy of the terminology.

The only language, so far as I know, which has a correct and really generic term for subterranean ice formations, is the French in its word *glacière*. The French and Swiss say *glacières naturelles* of ice deposits formed naturally underground; and *glacières artificielles* of ice houses. *Glacière naturelle* is comprehensive and accurate. It covers all the rock formations and suggests also the mode of formation of the ice. It likewise implies the strong resemblance between natural ice deposits and artificial ice houses. It might be well, therefore, if the French term *glacière* were adopted as a generic term for all underground ice formations. As, however, there is little likelihood of this happening, the question arises as to the best English equivalent or equivalents. These

seem to be "freezing cavern, freezing talus," etc., "natural refrigerator" or "subterranean ice formation." "Natural refrigerator" and "subterranean ice formation" are more generic than "freezing cavern, freezing well," etc.; but the latter have the advantage of suggesting immediately that reference is made to the hollows of the earth which at times contain ice; and, therefore, they are the best terms, perhaps, which can be chosen in English.

Another point in the terminology of this subject has reference to subterranean hollows where draughts issue or enter. Such hollows are found in all parts of the world and are known usually in English as "blowing caves" or "cold current caves." The Germans speak of them as *windröhren* or *windlöcher*. In my first paper about caves,[12] I used the word "windhole" which I translated from the German. The term "windhole" seems to me preferable to "blowing cave" or "cold current cave" in that it is more generic. It applies to taluses or boulder heaps, or in fact, to any hollows where draughts issue or enter, whether these hollows are genuine caverns or not.

It is necessary also to explain here that "glacière" and "windhole" are not synonymous terms. It must be understood that a glacière or natural refrigerator is a place where ice forms and endures in a subterranean or semi-subterranean situation; and that *the presence of ice* is the criterion of whether a place is or is not a

[12] *Ice Caves and the Causes of Subterranean Ice*, November 1896, and March 1897.

glacière. Likewise it must be understood that a windhole or blowing cave is an underground hollow with at least two openings, and in which distinct draughts occur; and that the *presence of draughts* is necessary to constitute a place a windhole or blowing cave. A freezing cavern may or may not be a windhole, and a windhole may or may not be a freezing cavern.

Temperatures.—The phenomena of glacières are so closely connected with temperatures that it seems necessary at this point to mention some general facts in connection with subterranean temperatures, even if these still form a subject of some uncertainty, and one about which further observation is desirable. Subterranean temperatures may be grouped under three heads: 1, Ordinary or normal temperatures; 2, Temperatures above the normal or super-normal temperatures; 3, Temperatures below the normal or sub-normal temperatures.

1. In the great majority of caves, cellars and subterranean places of all descriptions, the temperature of the air is about the same, all the year round, as that of the ground. The frost of winter and the heat of summer penetrate the earth for some trivial distance, a few meters perhaps, and lower or raise the temperature of the ground temporarily. Below this there is a stratum where the temperature is found to vary but little the entire year and which, in a majority of cases, approximates the mean annual temperature of the district. Below

this invariable stratum, the temperature generally rises slowly, not at exactly the same rate everywhere, but in a regular increase. This increase of temperature averages 1° C. for every 32 meters. As most caves and cellars are of small depth and as they take their temperatures from that of the ground, it follows that as a rule their temperatures are moderate and pleasant. And as the air of the majority of caves and subterranean hollows is about the same as the temperature of the surrounding rock, it is correct to call subterranean air temperatures closely approximating the ordinary temperature of the ground, ordinary or normal temperatures.

As already stated, with an increase of depth, there is, in almost all cases, a regular increase of temperature. For this reason, mines, which are much the deepest hollows reached by man in the surface of the earth, are, as a rule, warmer in the lower levels: if deep, they are also hot. And this is so generally the case that warmer temperatures at the bottom of mines may be considered as normal.

2. In a few hollows close to the surface, there are temperatures much above the normal temperature of the ground. Such places are rare and abnormal.[13] The heat is generally due to the presence of hot springs or to some volcanic action in the immediate neighborhood. In the case of one cave close to the surface, the heat is due to some limekilns which are situated immediately

[13] Kraus. *Höhlenkunde*, page 86.

overhead.[14] Where these warm hollows are genuine caves it seems proper to call them "hot caves."

3. In a number of places, there are abnormally low temperatures underground either for the whole or only for part of the year. Although commoner than hot caves, yet the underground places with low temperatures are also rare and abnormal. They may be divided into two groups: 1, Those where the temperatures are lower than the normal, without becoming low enough for ice to form; and 2, Those where the temperature sinks so low, that ice forms.

It is difficult to make definite divisions among the various forms of natural refrigerators, but it is correct, probably, to classify them under five heads, in accordance with the different kinds of formations of the hollows in the rocks:

1. Gullies, gorges, and troughs where ice and snow remain.

2. Soil or rocks overlaying ice sheets.

3. Taluses and boulder heaps retaining ice.

4. Wells, mines and tunnels in which ice sometimes forms.

5. Caves with abnormally low temperatures, and often containing ice.

1. *Gorges and Troughs.*—Gullies, gorges and basins which retain snow and ice are fairly numerous in moun-

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[14] Grotte du Jaur. *Les Abimes*, page 160.

tain districts. They are generally ravines, or rock fissures, or hollows, in positions below the snow line where snow and ice are sufficiently protected, from sun and wind, to remain long after snow in the surrounding open country, at the same altitude, has melted away. Some of these gorges are small, some big. As a rule, they are deep and narrow.

In north-eastern Siberia, a form of permanent surface ice is found, which the Tungusses speak of as *tarinnen*, which means "ice troughs" or "ice valleys."[15] These *tarinnen* are broad valleys, with either a horizontal floor or one sloping gently in the form of a trough, over which the ice is spread in the form of a sheet. The Tungusses assert that the ice in some of these troughs never wholly melts away, although it lessens in quantity from the beginning of May till the end of August, after which it once more increases.

Subterranean Ice Sheets.—In several places in different parts of the world there are underground ice sheets which extend over large spaces; they are common under the tundras of Alaska; and there are fine examples on Kotzebue Sound,[16] on the Kowak River,[17] and along the Yukon River.[18] The "Ice Spring" in Oregon

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[15] *Bulletin de la classe physico-mathématique de l'Académie Impériale des Sciences de St. Pétersbourg.* 1853. Vol. XI, pages 305–316.

[16] See Part III: page 167.

[17] See Part III: page 167.

[18] See Part III: page 166.

seems to be a formation of the same kind. Several examples of these subterranean ice sheets are reported also from different parts of the Russian Empire.

A somewhat different kind of ice sheet was observed on Mount Etna. Sir Charles Lyell[19] speaks of it as a "glacier preserved by a covering of lava." He says Signor Mario Gemmellaro satisfied himself that nothing but a flowing of lava over snow could account for the position of the glacier. Ice sheets somewhat similar to these are reported from Tierra del Fuego,[20] and probably also such sheets occur in Iceland; and enormous heaps of ice covered with sand are found on Mount Chimborazo.[21] On the northwestern coast of Greenland, glaciers, whose flow has stopped, were observed buried under an accumulation of moss and grass.[22]

Taluses and Boulder Heaps.—Taluses and broken debris, and in general boulder heaps of all sorts, have interstices and openings between the boulders, and in these it occasionally happens that ice is found. This is most common among the taluses at the base of cliffs, but in some cases ice is found among broken rocks on the sides of gently sloping hills, or even on the plateaus of their summits. Sometimes the ice and snow on the

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[19] *Principles of Geology*, 11th Edition, Chap. XXVI.
[20] See Part III: page 190.
[21] See Part III: page 189.
[22] See Part III: page 165.

bottom of rock gorges all melts away, while further down, in the hollows of the boulders forming the floor, ice still remains. The rocks of which these ice bearing taluses are formed are generally gneiss, granite, limestone, sandstone, basalt or porphyry. Among such boulder taluses the phenomenon designated as *Windröhren* or *Ventarolen*, that is, windholes, is frequently found. Sometimes the air among such boulder formations is quiet, but as a general thing draughts pour out at the lower openings during the hot months, and blow into them during the cold ones.

Freezing Wells, Mines and Tunnels.—Subterranean ice is also found in certain places in connection with man's handiwork. In a few wells in the United States, the temperature in winter becomes abnormally low, and for four or five months these wells freeze up and become useless. A case of a freezing well was recently observed near la Ferté Milon in Central France.[23] Ice is reported also as forming in various mines in Europe, Asia and America; in fact, it is not an uncommon occurrence. Occasionally, also, ice forms in tunnels.

Cold Caves.—Caves with abnormally low temperatures may be divided into two classes. First, caves where the temperatures are lower than the normal, without becoming low enough for ice to form; and second, caves where the temperatures sink so low, that ice forms.

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[23] See Part I.: pages 74, 79, 89. Part III.: page 206.

Caves where the temperatures sink below the normal, but in which ice does not form either in winter or in summer, are found in several places in different parts of the world. They are termed in French *cavernes froides* and in German *kalte höhlen.* There are but few data from reliable observers about such cold caves. Some descriptions are given without thermometric measurements, and the statements that the caves are cold, mean nothing beyond the fact that they feel colder than the outside air. It is, however, conclusively proved that cold caves exist, and that while they are not freezing caverns, yet that they have a temperature lower than the mean annual temperature of their district. In fact, the assumption, which had passed into an axiom, that caves always have the same temperatures as the mean annual temperature of the district, must certainly be given up. Cold caves are generally in one of two shapes: 1, in the shape of a sand glass,—two cones above each other meeting at the narrowest point—where the upper cone lets the heavy cold air descend easily, while the lower bell shaped cone prevents its escape; and 2, where two sink holes open into one pit, which is in the shape of a bell.[24]

Glacière Caves or Freezing Caves.—Caves where the temperatures sink so low that ice is able to form, are found in many different rock formations and in various positions, shapes and sizes. The rock formation of freez-

[24] *Les Abimes,* page 563.

ing caverns is generally limestone, but sometimes it is marble, lava, basalt, gneiss or granite. In all cases, however, the rock is either porous or else it is broken and fissured, as otherwise the water supply necessary to the formation of ice could not find its way in.

Glacière caverns may, for the sake of convenience, be classified into several classes, according to their position or to their form. The lines of transition between them, however, are so indefinite in nature, that it is often difficult to specify a cavern as belonging to any special type. The most important factor in classifying glacière caves is their position. Under this head there are two main divisions: first, pit caves; second, cliff caves.

Pit caves are those where a pit or pits open into the ground, and the ice is found at the bottom. Sometimes there is no roof, when the place may be called a gorge: this occurs at Ellenville, where the roof has fallen. Again, the pit itself is more or less roofed over and the ice is found mainly or wholly under the roof: this is the case at Haut d'Aviernoz, at the Friedrichsteinerhöhle, at Saint-Livres, and at Saint-Georges. Sometimes the pit takes the form of a descending tunnel, leading into a hall or chamber, in which the ice lies under a rock roof: this happens at Chaux-les-Passavant. In all these pit caves the body of the cave is below the entrance, and most of them are fairly well lighted by daylight throughout. Generally there is only one pit, but occasionally there are two connected underground, as is the case at La Genollière.

Cliff caves are those where the entrance is at the base or in the side of a cliff. Frequently the cave is in the shape of a hall or chamber, which begins directly at the entrance, and which may be large or small. This kind always has a down slope directly from the mouth. The Kolowratshöhle, Dóbsina and the Grand Cave de Montarquis may be mentioned as examples. In some cases there is a pit at the base of a cliff and there is a slope leading down to the cave, somewhat in the form of a tunnel; this is the case at Manchester and practically also at Roth. Again there is a more or less long gallery between the entrance and the glacière, which is always below the level of the entrance. The Schafloch, Démenyfálva and Decorah may be cited as examples. As a rule the gallery slopes down from the entrance, but sometimes the floor rises and then sinks to the glacière. The top of the entrance, however, is always higher than the highest point of the floor, as otherwise the cold air could not get in. This is the case at the Frauenmauerhöhle, and, apparently, also at the Posselthöhle. In one case, at Amarnath in Kashmere, the floor is said to rise to the roof at the back; but as the entrance is nearly as big as the floor area, the ice formations must also be below the level of the top of the entrance.

The dimensions of glacière caves vary greatly. Some are large, others are small. Saint Georges, a roofed pit cave, is some twenty-five meters by twelve meters, with a depth of about twelve meters. Chaux-les-Passavant,

a cave at the end of a pit tunnel, has a diameter of some twenty-seven meters. The measures of Dóbsina, a cave at the bottom of a cliff, are given as follows: Height of roof above ice floor, 10 to 11 meters; length 120 meters; breadth, 35 to 60 meters, and surface about 4644 meters. The Frauenmauerhöhle is a gallery about one hundred meters long before the ice floor is reached, and this is some fifty meters more in length by about seven meters in width. The glacière cave near Frain, on the contrary, is so small that one can only crawl in some two or three meters. In fact, glacière caves vary in size between great halls and little tunnels where one cannot stand up straight.

The entrances of glacière caves also vary greatly in their dimensions. For instance, the Friedrichsteinerhöhle is on one side of a huge pit and is as large and deep as the pit. Saint Georges, on the contrary, has, near one end of the roof, a couple of holes, some three meters in diameter. The entrance to the Schafloch is four meters wide by four meters seventy centimeters high, while the entrance to Roth is not over one meter each way.

A classification of subterranean ice formations, and one which applies to all the different forms, is into permanent and periodic glacières. When in any underground spot, ice remains throughout the year, the place may be called a permanent glacière; when on the contrary the ice melts away for part of the year, the place may be called a periodic glacière. This classification, which several observers have used already, is convenient and valuable.

Movements of Air.—Another classification of glacières can be made in accordance with the movements of air underground. Glacières may be divided into those where there are no strong draughts in summer and those where there are draughts: or into "apparently static caves"; and "dynamic caves" or "windholes." The first class includes those caves where there is one or more openings close together and those above the body of the cave. In such hollows the air in summer is nearly still, while in winter there are distinct rotary movements of the air as soon as the temperature outside is lower than that within. Almost all glacière caves belong to this class of caves without strong draughts in summer. Sometimes, however, ice is found in hollows where there are two or more openings, at different altitudes and at different ends of the hollow, and where there are draughts. Occasionally, also, there are fissures in the sides or rear of apparently static caves, which allow something like draughts at times, as is the case at the Grand Cave de Montarquis.

Professor Thury of Geneva coined the terms "static cave" and "dynamic cave" which have come largely into use since, and which practically correspond to the German terms *eishöhle* and *windröhre.* I do not think the term "static cave" accurate, and prefer the term "apparently static cave" or "cave without distinct draughts." For although there are many caves where the air seems stagnant at times, and there are no distinct perceptible draughts, still that the air is really stagnant all summer appears to

me doubtful, and it seems as if the movements of air were distinctly apparent only in certain caves and not in others. Air which is apparently stagnant is found in both pit and cliff caves mainly in the summer months, but even in these I have noticed several times in summer slight movements of air, especially near the entrance. I could not exactly feel the air moving, but by lighting a cigar the smoke could be seen borne outwards exceedingly slowly. At the entrance of the Kolowratshöhle I think there was a faint outward current when I was there. The day was hot and windless, and as the cold air met the hot outside air it formed a faint cloud or mist at the mouth of the cavern. At Saint-Georges, although the air seemed tranquil, I found that the smoke of my cigar ascended rapidly just below the hole in the roof, showing an ascending air current. In the double cave of Chapuis, I found one cavern filled by a little lake over which there was a draught.[25]

From the few winter observations we have, there can be no doubt that in winter the movements of the atmosphere are lively, the break in the air column occurring as soon as the outside temperature is lower than that within, when the outer air immediately begins to sink into the cave.[26]

If I have doubts as to the existence of absolutely static

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[25] See Part IV.: Butler, page 308.

[26] See Part III.: Chaux-les-Passavant, page 203; Saint-Georges, page 220.

caves, it is different about dynamic caves. When a subterranean hollow goes through rocks, with one opening higher than the other, there will surely be distinct draughts. These dynamic caves exist in many parts of the world under such names as cold current caves or blowing caves or windholes. Sometimes they are fissures in broken limestone. Often they are the cracks between piles of boulders. A cool air generally pours from the lower opening in summer while the cold air pours into it in winter, the draught being then reversed. At the upper opening the operation takes place in the opposite way, the hot air being sucked in in summer, and given out in winter. Sometimes, however, changes take place, according to the differences in the outside temperature, in the direction of the air current in the course of a single day.

The causes of the movements of air in these windholes are exceedingly simple. The movements of air depend on the fact that in summer the air in the tube becomes colder from contact with the rocks and, therefore, heavier than the air outside, and by gravity the heavy inside air displaces the lighter outside air and comes rushing out at the lower opening. This leaves a vacuum, which is filled by the warmer air dropping into the tube from above. In winter on the contrary, the air within the tube is warmed by contact with the rocks and becomes lighter than the air outside. It, therefore, rises and streams out from the upper opening, and the vacuum is filled by the heavy cold air pushing in at the lower opening.

angles and fractures visible on glacier or iceberg are absent. Instead of seracs and crevasses, broken ice falls, or piled up ice floes, we have hanging stalactites and rising stalagmites, smooth ice floors and curved ice slopes. This difference is of course due to the fact that most subterranean ice is formed from the drip from the roof or the sides of caves, and because the factor of motion—which plays so large a part in the shaping by fracture of overground ice—is practically wanting.

The most striking forms of subterranean ice are the ice stalactites and stalagmites. They descend from the roof as icicles or rise from it as rough cones or pyramids. The icicles are of all sorts of shapes and sizes: sometimes they are tiny; sometimes they grow downward till they reach the floor and form regular columns, in some cases no less than eleven meters in height.

The ice stalagmites likewise are of all sorts of shapes and sizes, some of them growing to a height of seven or eight meters. Occasionally they have hollow bases, but this is rare. How these hollow cones are formed is a still uncertain matter; but it is in some way by the action of the drip. At the Kolowratshöhle I saw the drip from the roof cutting out in July the basin, whose tall remaining sides suggested that early in the spring it was probably a hollow cone. The cone at the Schafloch of which I saw one half remaining, could only be accounted for by some action from the drip.[28] The warmth of the

[28] See Part IV.: Thury, page 287; Browne, page 290.

rock floor may help perhaps also, in melting away some of the base of the hollow columns.

The frozen waterfalls which issue from fissures in the rock walls of caves are another form of ice seen only below ground. For lack of a better name, I call them fissure columns. A peculiarity of these is that, while the rock fissure is more or less rectangular or at least sharp angled, the ice column issues in a rounded stream. Sometimes these fissure columns stream over the rock; sometimes they spring out far enough from the rock to be quite away from it. They vary from about one to five meters in height, and at the base they almost always spread out in a shape resembling that of a fan.

The ice on the bottom of caverns of course takes its shape from the form and angles of the floor of the caves. If the bottom is level or nearly so, the ice lies on it as a sheet or floor. If the bottom of the cave is sloping, the ice follows the angles of the slope, forming an ice slope or ice wall, and sometimes becoming nearly or quite vertical. These ice slopes distantly resemble the portions of glaciers called an ice fall, with the great difference, however, that there are no crevasses, not even tiny ones.

Occasionally, slabs of ice are found reposing in a fractured sheet over a solid ice floor. This means that a lake has formed on this spot in the spring, frozen over, and then run off, leaving its frozen surface in broken pieces on top of the under ice.

Another kind of frozen water is the hoar frost which forms on the rock roofs and walls. This is not at all rare. It is an open question whether this is not the same thing as that which has been described as subterranean snow.[29] I found myself in Dóbsina a small sheet of what to look and touch was snow. I wrote of this as snow in my first paper about glacières[30], but I am of the opinion now that it was the hoar frost detached from the roof and not genuine snow.

At Dóbsina, also, I noticed that the ice of the ice wall of the Korridor assumed a stratified or laminated form. Mr. John F. Lewis of Philadelphia suggested to me that this was probably due to a precipitation of the hoar frost from the roof, and I think his explanation is correct. The hoar frost forming at a certain degree of cold, would doubtless be precipitated at a rise of temperature, and would then act much as do the different layers of snow in the upper portion of glaciers.[31] It would consolidate gradually, layer over layer, and form strata, producing the banded or laminated structure visible in the vertical ice of the Dóbsina Korridor.

The ice in caverns is sometimes found with a structure which is, I believe, of rare occurrence above ground. This is when it takes the shape known as prismatic ice, which means that if a lump is broken

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[29] See Part III.: Ziegenloch, page 247; Creux de Souci, page 207.

[30] *Ice Caves and the Causes of Subterranean Ice*, November, 1896, and March, 1897.

[31] Whymper: *Scrambles amongst the Alps*, 1871, page 426.

from a column or icicle, the fracture will show regular prisms. This phenomenon is not as yet satisfactorily accounted for; the only thing certain about it is, that it does not occur in ice of recent formation. From my own observations, I should say that ice became prismatic at the end of summer; at least I have always found it in August or September rather than in June or July.[32]

Besides building up ice heaps, the drip, also, has the function of destroying its own creations. If there are no crevasses, there are holes and runnels. These are generally found at or leading to the lowest point of the ice floor. Occasionally the holes are deep, sometimes many meters in depth. They are certainly cut out by the melting water, to which they offer an exit; in fact they are a part of the drainage system present in all glacière caves, where there must be some outlet for surplus water at or near the lowest point: and as the caves are always in porous or broken rock, the drainage takes place through the cracks and fissures.

The drip produces also the exact opposite of pyramids in the shape of ice basins. These are cut in the floor by an extra strong drip from the roof at those spots. Basins exactly like these are not seen on glaciers. Not infrequently they are full of water of considerable depth.

Lakes and pools are found in glacière caves. Sometimes they are on the ice floor, and in this case they are due either to rain-water collecting faster than it can

[32] See Part IV.: Browne, page 289; Lohmann, page 303.

flow off, or else because the cave is in a state of thaw. Sometimes these pools are among the rocks in one part of a cave, while the ice is in another part.

I have said above that motion in subterranean ice is practically wanting. This is proved by the lack of crevasses on the ice slopes or ice walls, and also by the fact that basins and cones appear year after year in the same spots, where they remain whether they are increasing or diminishing. But this statement cannot be held to cover the entrance snow and ice slopes of some of the open pit caves such as the Gottscheer cave, or Saint-Livres or Haut d' Aviernoz. Here the snow, which falls on the entrance slope, must gradually gravitate to the bottom. The question is whether it only descends in the shape of water after melting or as snow before solidifying; or whether it ever slides down at all after becoming somewhat solidified. Probably, however, the ice of these slopes, judging from the fact that crevasses are entirely lacking, remains stationary.

Color Effects.—The color effect of every glacière cavern has a certain individuality, according to the color of the rocks, the quantity of ice, and the amount of daylight admitted through the entrance. In my opinion, the white note given by the ice, makes a fine glacière cave the most beautiful of all subterranean hollows. In this respect it seems to me that they are similar to high Alps, which are certainly most impressive with coverings of snow and glacier.

There are, however, two distinct notes in the color effects of glacière caves and these may be described as the partly subterranean, or as the wholly subterranean. In the former case the local tints stand out more clearly. For instance, at the Kolowratshöhle the ice is beautifully transparent and of a pale ochre-greenish hue: the limestone rocks are streaked with iron, and thus have a reddish hue, while, owing to the entrance admitting plenty of daylight, the effect is only semi-subterranean. Again, at Chaux-les-Passavant plenty of daylight is admitted: the rocks are a yellowish brown, and the ice is white and blue. At the Schafloch or the Frauenmauer, on the contrary, the effect is wholly subterranean: daylight is so completely absent that black is the predominating note, the ice itself looking gray. Dóbsina is an exception, as, thanks to the electric light, white is the conspicuous tone, even though rocks and shadows dull many places and corners into a sombre gray.

More than once, on returning to daylight from the intense blackness of a cave, I have seen the rocks near the entrance appear a dark blue color, exactly simulating moonlight. This effect is common to both glacière caves and ordinary caverns. It is a striking but rare phenomenon, and depends apparently on the shape of the cave. This moonlight effect only seems to occur when a cave makes an elbow directly after the mouth and then goes straight for some distance. When the daylight is actually in sight, the moonlight impression vanishes.

Carbonic Acid Gas.—Carbonic acid gas, judging from the most recent explorations, is more of a rarity in rock caves with normal temperatures than is generally supposed. There appears to be only one case on record where this gas was observed in a cold cave. This was in the Creux-de-Souci,[33] which is rather a cold than a freezing cavern, but which on one occasion was found to contain snow, and whose temperature is always extremely low. From the present state of knowledge, therefore, it may be assumed that if carbonic acid gas does form in glacière caves, it does so only seldom.

Fauna.—No attention whatever has been paid, practically as yet, as to whether any distinctive animal life exists in glacières. So far, I have seen none myself. The Rev. G. F. Browne, in four instances, found a large red-brown fly nearly an inch long, which is supposed to be *Stenophylax Hieroglyphicus* of Stephens; and at Chapuis, he obtained an ichneumon of the genus *Paniscus.* At Font d'Urle, Monsieur Villard captured a blind specimen of a coleoptera, *Cytodromus dapsoïdes.* A variety of rotifer, *Notholca longispina,* is now living in the Creux-de-Souci. In Skerisora, remains of bats have been found, not very different from those now living in the neighborhood.[34] It is, in any case, certainly remarkable

[33] See Part III.: page 207.

[34] See Part I.: Ausable Pond, page 81, and Part III.: Creux-de-Souci, page 207; Font d'Urle, page 213; Chapuis, page 216; La Genollière, page 219; Skerisora, page 245.

that the same kind of fly should have been discovered in several glacières in different localities; and it may some day be shown that there is a special insect fauna. Certainly the subject is worth investigating.[35]

Flora.—The flora of glacières has been as little observed as the fauna. There are scarcely any references to such a thing as glacière plant life in literature. Whether there is a special flora in any glacière cave is still an open question. In the cases of several boulder taluses, there is no doubt that, even if there is not a special flora, at least that the plants near the ice beds are greatly retarded every year in their development. Probably the flora among the boulders blooms a month or six weeks later than the flora in the immediate vicinity. In the cases of the Cave of Paradana and of the Kuntschner Eishöhle it is reported that the plant life becomes more and more arctic in character towards the bottom of the pit.[36]

Paleontology.—No paleontological remains have as yet been reported from glacière caves. No bones of animals have been found, except those of bats in Skerisora[37]

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[35] In June, 1899, I mentioned these facts to Monsieur Armand Viré, director of the Biologic Laboratory in the catacombs of the Jardin des Plantes in Paris. He was much interested, and promised to make a careful investigation of the matter.

[36] See Part I.: Ausable Pond, page 80; Giant of the Valley, page 83, note 7; Ice Gulch, page 85; Spruce Creek, page 91. See Part III: Spruce Creek, page 188; Paradana, page 237; Kuntschner Eishöhle, page 241.

[37] See Part III.: Skerisora, page 245.

and a few of the common genus *bos*.[38] No relics of the handiwork of man have been discovered; nor, indeed, with the exception of the skeletons found in the cave of Yeermallik in Kondooz,[39] anything which reveals the presence of man in glacières or that they were ever used for habitation. The reason that there are so few remains in glacière caves is undoubtedly because their temperatures are too low for their occupation by animal or man; but, from the evidence afforded by their non-occupation, may be drawn the valuable inference that the glacière caves of to-day were glacière caves long ago.

Legends and Religion.—There are scarcely any legends connected with glacières. I know only of one about one of the caves of the Mont Parmelan.[40] Nor does there seem to be any reference to glacière caves in works of fiction. Dante makes his last hell full of an ice lake, but an attentive perusal fails to reveal a single line which in any way describes or suggests a glacière. In at least two cases,[41] however, the ice in caves is connected with religion, as in Kashmere, the Hindoos, and in Arizona, the Zuni Indians, either worship or pray at glacière caves, overawed, from some mystical feeling, by the permanence of the ice formations which they connect with their deities.

[38] See Part I.: Saint-Livres, page 68.

[39] See Part III.: Yeermallik, page 261.

[40] See Part III.: Glacière de l'Enfer, page 216.

[41] See Part III.: Amarnath, page 262; Cave, White Mountains, Arizona, page 176.

II.

The cause of the formation of subterranean ice is undoubtedly one of the most intricate problems in connection with caverns. Various theories have been advanced why ice is found in certain caves and not in others. Some writers have held that it is a remnant of a glacial period; others that it is owing to the presence of salts in the rocks; some have said that it is due to the rocks retarding waves of heat and cold; and still others think that it is formed by pressure on the percolating waters. Many of these theories were formulated in explanation of the belief of peasants living near the caves, who almost always say that the ice is formed in summer and melts in winter. Most scientific observers on the other hand claim that the ice is due to the cold of winter, and a few think that it is formed or helped by draughts and by evaporation and expansion of the air. The variety of opinions put forth, show at any rate the intricacy of the problem.

All my own observations have tended more and more to make me believe that the cold of winter is the cause of the ice. Before elaborating my own views, however, I wish to take up seriatim the theories which have been formulated, principally in explanation of the belief that the ice was a summer product, and to give my reasons for my disbelief in them.

Glacial Period.—The first theory, perhaps, to touch on, is the one that the ice is a remnant of a glacial

period. This seems to occur to many persons as a solution of the question when they first hear of glacières, and it has been several times propounded to me, and naturally enough, always by scientific men.[42] Still I do not think it has ever been held by anyone who had made a study of glacières.

The theory is, indeed, untenable in regard to freezing caves, as it does not accord with the observed facts of the yearly disappearance of the ice in many caves and taluses. At Szilize every year the ice has disappeared pretty completely by November, and the cave is free; but in April or May the floor is again covered with ice, and columns and icicles have formed on the roof and sides. At La Genollière the cave is used by the people of the neighboring châlets, through the spring and early summer, to help in the operation of butter making; by the middle or the end of August it has entirely disappeared, but is found formed afresh the following spring. At the Rumney Talus, at the Cave of Decorah, at the Gorge of Ellenville, and at the Williamstown Snow Hole, I found no snow or ice.[43] Yet it is abundant in all these localities in the spring. Too many examples of the complete melting away of the ice every year can be cited, to permit any doubt: glacière caves are not connected with a glacial period.

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[42] See Part IV.: Hitchcock, page 284; Bonney, page 291; Dawkins, page 292.

[43] See Part I.: Rumney, page 85; Decorah, page 88; Ellenville, page 91; Williamstown, page 98.

Though it may be stated positively that the ice in caves is not a remnant of a glacial period, yet this cannot be done so authoritatively about subsoil ice sheets and freezing wells. At Brandon, Owego and Decorah the gravel was found frozen at the time the wells were dug, and it is of course impossible to determine for how long a time this was the case previous to the digging. The proofs, however, are so strong that the ice re-forms every winter at such freezing wells, that they may be considered as in every respect following the same general laws as glacière caves. That the ice in these wells is not the remains of a glacial period, seems proved moreover by the work of the Boston Natural History Society, which sank two wells at Brandon near to the Freezing well. One of these was only twenty-one meters distant and went through the same gravel drift. Yet it did not strike ice.[44] A somewhat similar state of things appears to be the case with the Centennial Lode and other lodes on Mount McClellan,[45] where the causes also seem to be local, as there is no ice in mines on neighboring mountains.

The Summer's Heat Theory.—The natives and peasants in the neighborhood of glacière caves generally believe that the ice of caves is formed in summer and melts in winter. I have met with this belief everywhere in Eu-

[44] See Part IV. : Hager, page 282 ; Hitchcock, page 284.
[45] See Part III. : Rifts of Ice, etc., page 174.

rope; in the Eifel, Jura, Swiss Alps, Tyrolese Alps, and Carpathians: and also occasionally in the United States. Peasants and guides tell you with absolute confidence: "The hotter the summer the more ice there is." The strange thing is that any number of writers[46]—sometimes scientific men—have accepted the ideas and statements of the peasants about the formation of ice in summer, and have tried to account for it.

The belief of the peasants is founded on the fact that they scarcely ever go to any cave except when some tourist takes them with him, and, therefore, they rarely see one in winter, and their faith is not based on observation. It is, however, founded on an appearance of truth: and that is on the fact that the temperatures of glacière caves, like that of other caves or that of cellars, are colder in summer than the outside air, and warmer in winter than the outside air. Possessing neither reasoning powers nor thermometers, the peasants simply go a step further and say that glacière caves are cold in summer and hot in winter.

Professor Thury tells a story to the point. He visited the Grand Cave de Montarquis in midwinter. All the peasants told him there would be no use going, as there would be no ice in the cave. He tried to find even one peasant who had been to the cave in winter, but could not. He then visited it himself and found it

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[46] Among them may be mentioned: Boisot, 1686; Valvasor, 1689, Behrens, 1703; Billerez, 1712; Bel, 1739; Rosenmüller and Tillesius, 1799; Sartori, 1809; Pictet, 1822; Scrope, 1826; Murchison, 1845.

full of hard ice. On his return he told the peasants of his discovery. They were staggered at first, finally one exclaimed: "It makes no difference; in genuine glacières there is no ice in winter."

It will be difficult, probably, to eradicate this belief and the consequent theories among the uneducated people in the vicinity of glacière caves, for their imperfect observations will keep it alive. In refutation, it may be said that the winter's cold theory is the direct opposite of the summer's heat theory, and that all the observations and all the facts which prove the one, disprove the other.

Within two or three years, however, the formation of small quantities of ice has been observed during the summer months in one or two caves. This has taken place in mountain caves situated at a high altitude at times when the air outside has dropped below freezing point during the night. There is, therefore, nothing inconsistent in this fact with the winter's cold theory: indeed it is only a widening of it in the meaning of the word winter.[47]

Chemical Causes.—Non-scientific persons, on first hearing of glacière caves, almost always suggest that to form the ice there must be salts in the rocks. Probably they connect unconsciously in their minds "ice caves" and "ice cream."

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[47] See Part III.: Beilsteinhöhle, page 235. Part IV.: Professor Cranmer, page 310.

Chemical causes, however, have never appealed to scientific men.[48] There are only two places I know of where salt is reported. One is the Ice Spring in Oregon, which is said to be slightly saline in taste; the other is the Cave of Illetzkaya-Zatschita, where the gypsum hillock, in which the ice is found, overlies a bed of rock salt. Repeated experiments in letting lumps of glacière ice melt in my mouth have convinced me personally that in all cases the water is exceedingly pure and sweet, a fact mentioned in the very first notice extant about glacières, the letter of Benigne Poissenot in 1586, who speaks of the deliciousness of the water in Chaux-les-Passavant. To sum this matter up briefly, it can be safely asserted that all causes, which would fall under the head of "Chemical causes," must be entirely eliminated as possible cold producers.

Waves of Heat and Cold.—While Sir Roderick Murchison was studying the geology of Russia,[49] he visited Illetzkaya-Zatschita and was puzzled to account for the ice formations. He thought, at first, that they were due to the presence of salt, but recognizing that this was not correct he submitted the case to Sir John Herschel, who, rejecting the evaporation or condensation of vapor as the cause, argued that the ice was due to waves of heat and cold, and that at certain depths in the interior, the cold

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[48] See Part IV.: Billerez, page 270; Hacquet, page 271.

[49] *The Geology of Russia and the Ural Mountains*, vol. I., pages 184–198.

wave arrived in midsummer and the heat in midwinter. Murchison declined to assent to this doctrine, asking why one cave should present this exceptional occurrence, when the numerous other rents and openings in the same hillock were free from ice. The impossibility of the heat and cold wave theory was so completely shown by Murchison's objection, that it has never again been brought forward.

Capillary or Compressed Air Theory.—The possibility of compressed air causing subterranean ice to form seems to have been first authoritatively formulated by Mr. N. M. Lowe, of Boston.[50] His theory in brief is this:—Bubbles of air drawn into water flowing down through fissures in rocks are liable to a continually increasing pressure. When the air has reached the bottom and is liberated in the cave, it will be from a pressure equal to the height of the column of water, and it will have lost by connection in the mass through which the conduit passes, the heat due to its compression; and on being liberated, it will immediately absorb from the air and the water in the cave, the heat which it has lost in its downward passage.

Several scientific observers have rallied to this idea.[51] One of the Hungarian residents at Dóbsina, a doctor, whose opportunities for observations are unrivalled, told

[50] *Science Observer.* Boston, 1879, vol. II., page 57. See Part IV.: Silliman, page 279; Olmstead, page 282.

[51] See B. Schwalbe, *Ueber Eishöhlen und Eislöcher*, page 56.

me—if I understood him correctly—that he believed in the capillary theory.

There are many facts, however, which militate against the compressed air theory as applied to caves. Almost all caves receive some drip through fissures, and yet there are many thousands of caves which never contain ice, and whose temperature scarcely varies the year round. Especially against the theory is the fact that glacière caves are never known in hot countries. If the theory were correct we should, for instance, sometimes find ice in such caves as those of Yucatan described by Mr. Mercer.[52]

There are also some mechanical difficulties in the way. Mr. John Ritchie[53] touches them when he says: "If the passage through which the water flows down is at all tubular the column will be subjected to the usual hydrostatic pressure." The word *tubular* is the hard one to answer. Limestone rock fissures are certainly not tubular. They have all sorts of shapes and angles and corners, every one of which would interfere with anything like a regular pressure.

This latter objection would not apply to borings in mines. I have been assured that in some borings in Western mines ice has been formed by pressure, and there may be truth in this, although I doubt it, as I have yet to hear of ice in any mines in warm latitudes. Mr. John Ritchie[54] has suggested, also, that if compressed air

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[52] *The Hill Caves of Yucatan.*

[53] *Boston Transcript*, January 2d, 1897.

[54] *The Happy Thought.* Boston, January 23d, 1897.

does not perhaps act strongly enough to form ice, yet it may help in keeping the temperature low and aid in the formation of draughts in caves and boulder heaps. At present, however, I can see no reason to think that the ice in caves is due to compressed air.[55]

III.

I have already said that I believe that the cold of winter is the cause of the ice in caves. To make this clearer, I may say that I look on glacières as the last outcrop, the outside edge, so to speak, of the area of low temperatures, which has its culminating point in the Northern Hemisphere in the Arctic Ocean, Greenland and Siberia, and in the Southern Hemisphere in the Antarctic; and which is manifested to us in the snows of mountain peaks, and immediately round us in frozen ponds and rivers and snowy blizzards; and which, as it disappears each summer, leaves its last traces in our latitudes in sequestered gorges and convenient caverns. In every case, it seems to me, glacières are simply refrigerators, which preserve the ice and snow accumulated in them during the winter. They all follow the same general laws as to the origin of their contents, modified only in slight degree according to the varying natural local conditions, such as the water supply, or the protection from sun and wind, or the thickness of the overhead rock, or the altitude or latitude. I cannot see that there is any-

[55] See Part I.: page 89.

thing remarkable about the fact that the cold of winter is able to penetrate and make itself felt sometimes for a slight depth in the earth's crust; a depth, so far as yet known, never exceeding one hundred and fifty meters. It seems to me that glacières only emphasize a law of nature, which has doubtless been formulated many times in connection with springs and phreatic waters, and that is, that where we find cold waters underground, we may be sure that they have penetrated from the outside.

If we look first at the mode of formation of overground perennial ice, that is, of the ice of glaciers and of rock gorges; and then at the evidences of the mode of formation of underground perennial ice, in boulder heaps, wells and caves; we will soon see that the transitions between them are gentle in character and that there is nothing unnatural about the formation of the ice in glacières.

Glaciers.—Everyone now knows the main characteristics of glaciers. They are formed in parts of the earth where the land or the mountains reach to the region of perpetual snow. The snows fall from the sky, and accumulate into a snow cap, which by its own weight and by melting and regelation, gradually changes to ice. This, by the laws of gravitation, descends to lower levels, and in mountain valleys extends sometimes far below the snow line into the region of cultivated fields. These valley prolongations of the perpetual snow

caps are the glaciers. The important point to notice here, is that the formation of glaciers is originally entirely due to the precipitation of moisture by cold in the upper portions; while the destruction of glaciers is due to the action of heat melting the ice in the lower portions, where they disappear in the shape of streams of running water. It is, therefore, not surprising that the greatest glaciers are found in the Arctic and Antarctic regions and in the highest mountain ranges; and that in the tropics glaciers are either wanting or exceedingly small.

Gorges and Troughs.—Gorges and gullies, where ice remains over, are a transitional form between glaciers and glacières. In many mountain ravines or canyons, the enduring snow consists principally of the avalanches which have fallen from the heights above during the winter and solidified in the bottom of the ravines. Freezing gorges proper, however, are not dependent on avalanches for their supply, but they receive the accretions to their ice directly from the winter snows. These fall into the gorge itself and by melting and regelation gradually solidify into a mass of ice which, when well sheltered against sun and wind, remains over sometimes till the following winter. By their mode of formation, therefore, it is evident that the ice in these gorges has some of the characteristics of glaciers; that it is due to the same prime causes as the ice of glaciers or the ice on ponds and rivers, namely the cold of winter; and in

fact, it is not far wrong to consider these gorges as miniature glaciers.

Freezing gorges, however, show, also, certain degrees of kinship to freezing caverns and taluses, principally in the protection afforded to the ice against external destructive influences. The ice is almost always found in positions where it receives little, if any, of the direct rays of the sun and, also, where it is scarcely, if at all, exposed to any winds. The sides of the fissures and surrounding trees generally afford the necessary protection. Some of the forms which the ice assumes in gorges, such as long pendent icicles, are also more characteristic of underground than of overground ice.

The freezing troughs or basins found in Siberia are evidently closely related to gorges, and the fact that the ice is found in less sheltered places may be explained by the high northerly latitudes of these troughs, in general between fifty-seven and sixty degrees.

The Winter's Cold Theory.—The places where ice is found underground differ in one important respect from gullies and troughs, and that is, in the fact that above the ice there is rock or soil, which, in true caves, takes the form of a roof. This causes some important distinctions between overground and underground perennial ice. It means that the ice is formed directly in the caves, and that it is genuine subterranean ice, and not, except perhaps near the entrance, solidified snow. The roof, while not admitting the winter snows, is, however, a pro-

tection against warm summer rains, and, of course, entirely cuts off radiation from the sky. If, therefore, it keeps out some cold, it also acts as a protector against heat.

That the cold of winter is the source of the cold which produces the ice which forms underground, and that it is through its influence, with the assistance of certain secondary causes, that some caves are converted into what are practically natural ice houses, seems to me the true explanation of the phenomenon of subterranean ice, not only since it is the simple and obvious explanation, but also because all the facts, so far as I have myself observed, are in accord with this theory.[56]

To form subterranean ice, just as to form any other ice, two things are necessary: the first is cold, the second is water. Cold is supplied by the cold air of winter, and water must in some manner find its way into the cave while the cold air is there.

The process is as follows: The cold air of winter sinks into and permeates the cave, and in course of time

[56] Among those who have written or said that the cold of winter plays a more or less important part in the formation of subterranean ice may be mentioned: Poissenot, 1586; Gollut, 1592; DeBoz, 1726; Nagel, 1747; Cossigny, 1750; Jars, 1774; Hacquet, 1778; Girod-Chantrans, 1783; Hablizl, 1788; Prevost, 1789; Townson, 1797; Humboldt, 1814; Dearborn, 1822; Deluc, 1822; Dewey, 1822; Lee, 1824; Reich, 1834; Hayden, 1843; Guyot, 1856; Rogers, 1856; Petruzzi, 1857; Smyth, 1858; Hager, 1861; Thury, 1861; Browne, 1865; Raymond, 1869; Krenner, 1874; Ritchie, 1879, Benedict, 1881; Schwalbe, 1881; Fugger, 1883; Trouillet, 1885; Girardot, 1886; Russell, 1890; Martel, 1892; Krauss, 1894; Lohmann, 1895; Balch, 1896; Cvijic, 1896; Butler, 1898; Kovarik, 1898; Cranmer, 1899.

freezes up all the water which, in the shape of melting snow or cold winter rain or spring water, finds its way in; and once ice is formed it remains long after ice in the surrounding open country has melted away, because heat penetrates with difficulty into the cave. The only effect of the heat of summer is to melt the ice.

The proofs, to my mind, of the truth of this view are 1—Glacières are always found in parts of the world where, during part of the year at least, the temperatures of the surrounding country fall below freezing point. 2—All observations by reliable observers show that the temperatures of glacière caves vary, but in a much narrower thermometric scale, with those of the outside air, that the temperatures are lowest, and as a rule below freezing point, during the winter months; and that the temperatures are highest, and as a rule above freezing point, during the summer months. 3—Ice is never found far from the mouth of caves, but always near enough for the cold air to get in. 4—Evaporation, according to my observations, is, as in all other forms of ice in nature connected mainly with the melting, not the freezing of the ice.

Geographical Distribution and Altitudes.—Glacière caves proper are found in various parts of Europe Asia, and America, mostly in the smaller mountain ranges or in the outliers of the snowy mountain chains; generally in limestone and occasionally in basaltic formations. There are a good many in the Jura; a

few in the Swiss and the Italian Alps; a number in the Eastern Alps of Tyrol and Carinthia. There are some in Hungary, several in Russia, one in Iceland, one on the Peak of Teneriffe, a number in Siberia, one in Kondooz in Central Asia, one in the Himálaya, one in Japan, and one in Korea. I have heard so far of over fifty glacières in North America, several of which are in Pennsylvania. From all over the world there are some three hundred places reported where subterranean ice is said to occur. This includes gorges, boulder heaps and freezing mines and wells, all of which exist in much the same localities as glacière caves.

All the glacières which I know of, are situated in a latitude or at an altitude where ice and snow forms for part of the year in the surrounding open country. None are reported from India or Africa, or in fact from any low-lying places in tropical latitudes. Most of them are found in middle latitudes, and only where during part of the year, at least, there is a cold season, that is, where for some time the thermometer stands below freezing point.

Glacières are, in general, at fairly high altitudes. The Schafloch is at 1780 meters; Skerisora in Transylvania at 1127 meters; Dóbsina at 1100 meters; the Glacière de Saint-Georges at 1208 meters. It is true that there is one freezing cavern in the sub-tropical latitude of Teneriffe, La Cueva de la Nieve; but it is at an altitude of 3300 meters, and where snow falls every year in the open on the Peak. Unless some freezing cave is here-

after discovered in a region where there is no ice in the open in winter, I do not see how the imperative necessity of the cold air of winter for forming the supply of ice can be controverted.

Thermometric Observations.—That the cold air of winter is the important factor in the production of cold is proved, also, by the thermometric observations recorded in various caves by different observers. They all tell the same tale: that the temperatures vary with those of the outside air, that they are lowest in winter and highest in summer. I quote in the "List of Glacières"[57] a few of those published; but there are many more, and they all show the same general characteristics.

A comparison of all the figures recorded proves that, as a rule—inside of glacière caves—from about the first of November to the first of July, there are winter temperatures, that is temperatures below freezing point; and from about the first of July to the first of November, there are summer temperatures, that is temperatures above freezing point.

The observations prove also that the inner temperatures vary less than the outer, that is that they range within narrower limits. They also show that the inner air is but slowly affected by the outer air when the

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[57] See Part III.: Decorah, page 178; Chaux-les-Passavant, pages 203–5; La Poujade, page 208; Montarquis, page 218; Saint-Georges, page 219; Schafloch, page 223; Kolowratshöhle, page 227; Schellenberger Eisgrotte, page 228; Frain, page 252; Dóbsina, page 253; etc.

latter is above freezing point, the inner temperature rising then only gradually. Per contra, when the outside temperature drops quickly much below freezing point, the inside temperature generally drops correspondingly at once, proving that the cold air has sunk by its weight into the cave. The observations also prove that the old idea that the temperature of caves is the same throughout, can no longer be considered correct. The observations also appear to show, that the temperature of a cave does not necessarily represent the mean annual temperature of a surrounding district. Observation is still entirely lacking on the mean annual temperature of glacières, so that one cannot speak definitely about the matter; but it seems likely that the mean annual temperature of a glacière cave is lower than the isotherm of its locality; and it seems more than probable that on the same isotherm different glacière caves may have different mean annual temperatures, varying with the elements of size, quantity of ice, position of body of cave and of entrance, water supply and other factors.

Ice near the Entrance of Caves and the Surface of the Soil.—An important proof that it is the cold air of winter which forms the ice is the fact that the latter is always found near the entrance of caves or near the surface of the soil. It never extends far within. To the best of my knowledge, ice has never been found two hundred meters from the entrance nor at any depth beyond one hundred and fifty meters. In all caves of

great extent, the temperature far in is about the same as that of the surrounding rock, and in all deep borings the temperature increases with the depth and at great depths the temperature becomes high. This nearness of subterranean ice to the outside air is one of the best proofs, that, paradoxical as the whole phenomenon appears at first, yet in reality it is an extremely simple matter.

The position of the entrance of a cave in relation to the body of the cave is an important factor in permitting the cold air to permeate and remain in the cave. In all the caves or gullies I have examined myself, the main mass of ice is well below the level of the entrance, and even if the latter is sheltered against the wind, it is not sheltered against the cold air of winter. This is heavy, and by its own weight sinks well down to the bottom, freezing up in course of time all the moisture that may drip from the roof, or that may come into the cave in the shape of melted snow or cold winter rain. The summer air, which is warm and, therefore, light, can only enter the cave with great difficulty; and, as a rule, before it dislodges the winter air and destroys the ice, another winter's freeze reverses once more the conditions. These principles seem to hold of every known glacière. It is true, that at the Frauenmauer, the floor of the cavern rises somewhat from the entrance; but the highest point of the floor is still below the level of the top of the entrance, so that the cold air can flow over the highest

point without difficulty. The same appears to be the case at the Posselthöhle; while at Amarnath in Kashmere, where the floor is said to rise to the back wall, the entrance is about as large as the area of the floor, so that the ice must also be below the level of the top of the entrance.

The position or situation of the entrance is important. In almost all cases it has a northerly exposure, and is sheltered against entering winds. If these two conditions do not exist the ice supply surely suffers. Sometimes the entrance is more or less tortuous. In some cases it is protected by a fringe of trees. Still, there is no absolute rule about entrances. The Friedrichsteinerhöhle faces about due south, and at midday in summer, the sun shines all the way down to the ice floor, causing mists to form. In the Kolowratshöhle, the entrance is badly sheltered against the wind and this undoubtedly affects the supply in summer and causes more rapid melting there than in some other cases.[58]

Freezing boulder taluses invariably have the ice near the surface, and probably it is never a dozen meters distant from the open air. These taluses are one of the strongest links in the chain of evidence proving the winter's cold theory. The snow and ice on the surface of the taluses and on the surface of the boulders in gullies melts away, while it still lingers underneath the boulders. It seems self-evident that the melting snow water has run to the lowest level and there congealed,

[58] See Part III. : Decorah, page 178.

nor mushy ice, the air was relatively dry and the sensation of cold not unpleasant. When I have visited a cave in August, the ice was soft and mushy, water was dripping from the roof, the atmosphere was moist, and the cold penetrating. It seems to me that the facts go to show that it is not evaporation which forms the ice, but the melting of the ice which fills the cave with moisture. If there are any draughts or movements of the atmosphere when above freezing point, then their tendency is to vaporize the ice.

The process of the formation of ice in relation to the atmosphere is as follows: the cold air permeates the cave and freezes up all the drip: the atmosphere becomes dry: gradually warmer air gets in and the ice begins to melt: then the atmosphere gets charged slowly with the vapor of the melting ice. This process is the exact opposite of the formation of ice by evaporation; it is the atmosphere which is made humid by the vaporizing of the ice, and by the drip. When the air is thoroughly saturated with the vapor, being scarcely renewed from outside and but a few degrees above freezing point, it undoubtedly retards evaporation, acts like a blanket and lessens the rate of melting of the ice.[63]

Everything I have personally observed in freezing windholes shows that in them also the cold of winter and not evaporation is the cause of the ice. They answer to the same tests as other glacières, of geographical distri-

[63] See Part IV.: Thury, page 285; Fugger, page 296; Trouillet, page 298.

bution and altitude, nearness of ice to the outside, thermometric observations, and dampness of the air when the ice melts. Equally with other glacières, the movements of air in windholes do not depend on the presence of ice, but the ice does depend on the movements of air and a water supply at the proper time. A proof that it is the cold of winter which makes the ice in windholes, is that the ice is always found at the lower extremity, for the reason that it is at that end that the cold air enters and to that end that the water gravitates. The reason that ice is more rarely found in windholes than in apparently static caves, is due to the movements of air. Unlike the caves where the heavy cold air preserves the ice by remaining pent up, as soon as the outside temperature rises the heavy cold air in windholes tumbles out at the lower opening and is replaced gradually by air at a higher temperature. This also flows out and when it is above freezing point, it naturally melts the ice and becomes humid: in fact, it vaporizes the ice as it passes, and dissipates the moisture into the outer air.

It is, however, certain, that in caves with a temperature some degrees above freezing point, when there is either running water or strong drips, evaporation may be, and sometimes undoubtedly is, a factor in lowering the temperature somewhat.[64] As in some windholes there

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[64] See Part IV.: DeSaussure, page 274. See also *Les Abîmes*, 1894, page 564.

is occasionally moisture on the rock surfaces where the air current passes, the evaporation from these surfaces doubtless lowers the temperature of the draughts, and it may be, also those of the rock surfaces, a little.

Further observations, however, will be necessary in regard to evaporation underground, as the data are still insufficient to make absolutely positive statements.[65] I fail to see any evidence to show that evaporation ever lowers the temperature of draughts underground below freezing point, only that it may help to lower them to something less than they would otherwise be. Taking all the facts which I have myself observed, and all I have read of in the reports of others, my own conclusion is that we have no proof that evaporation underground is ever strong enough to produce ice.

Time of Formation of Ice.—Everything I have seen points to the fact that ice begins to form in a cave as soon as the temperature of the cave has sunk below freezing point, whenever, from any cause, water gets into the cave. The cold may begin to penetrate caves as soon as outside frosts have occurred, that is in the fall months, about November; and as soon as the temperature inside sinks below freezing point, ice will begin

[65] Several observers consider evaporation as more or less of a factor in the production of cold underground. It is suggested also, that in certain cases, at high altitudes, evaporation tends to prevent the melting of the ice in windholes, but this is not proved, as yet. See Part IV.: De Saussure, page 274; Fugger, page 296; Trouillet, page 298; Martel, page 300; Lohmann, page 302.

to form, provided also that water gets into the cave, from rains or springs or any other source.

In the mid-winter months, although there is then plenty of cold, the water supply is generally lacking, as the outside moisture is mostly frozen up and the result is that the winter months are not those when the ice is mainly formed. Some is undoubtedly formed in certain caves whenever during the course of the winter a surface thaw outside furnishes water to the cave,[66] but in other cases this is not so and the ice does not appear before the spring. In all cases it is in the spring, before the cave has parted with its store of cold, and when both the air and the rock walls are chilled below freezing point[67] that the ice forms fastest. Then plenty of water is furnished by the melting of the snows and the unlocking of the brooks, and also by early spring rains. All this surface water runs through the fissures into the still freezing cave and there becomes ice. Not only the air, but also the rock walls are chilled below freezing point, and as the rocks part slowly with the cold stored in them, this cold helps to freeze the water pouring in.

The natural law in relation to time seems to be this: Ice may be formed in caves as soon as the outside temperature sinks below freezing point. In some caves it

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[66] See Part III.: Chaux-les-Passavant, page 203; Saint-Georges, page 220.

[67] See Part IV.: Townson, page 275; Thury, page 285; Trouillet, page 297; Schwalbe, page 298; Terlanday, page 301; Kovarik, page 307.

forms intermittently all through the cold months because there is a water supply. In other caves it only forms in the spring, because there is no water supply in the winter months. In all cases, however, the end of winter is the time when most of the ice is formed.

PART III.

LIST OF GLACIÈRES.

LIST OF GLACIÈRES.[68]

NORTH AMERICA.

Buried or Fossil Glaciers, North Greenland. (W. E. Meehan, *Philadelphia Ledger*, 1896.)—On Robertson's Bay is the plateau of the Verhoef Glacier, which is about 1500 meters long and 400 meters wide, and stands back only a few meters from the edge of the sea. This plateau, both top and sides, is a mass of flourishing vegetation, chiefly grass, which reaches above a man's knee. From among this verdure buttercups, poppies, cinquefoils and dandelions thrust their golden heads in wild profusion. Similar buried glaciers are found in many places along the fiords of North Greenland.

Mr. Meehan gives a simple explanation in connection with the Verhoef Glacier. He says that this glacier formerly extended out into the sea, and that while it moved forward, the clump moss, which struggles for existence in Greenland gorges, could do little more than hold its own. In course of time, from some unknown cause, the glacier receded to the point where it now discharges, the part in the water floating away in the shape of icebergs, and the part on the shore remaining stationary. This was the opportunity for the clump mosses. Caring nothing for the cold they crept slowly over the quiet mass of ice

[68] This list is necessarily incomplete, and only approximately accurate in many cases.

and made their way first in thin net-like layers, later in thick masses, till they reached the rocky shore. Year after year the mosses grew, the young plants trampling under-foot the older; until the latter, rotting, turned into a rich mould. The seeds of grasses and flowers found their way to this, blown by the wind or carried on the feet of birds. The plateau now is a garden of green, gold and white. How long this will last it is impossible to say, as any time nature may unloose its hold, and the frozen river once more pour down into the bay.

SUBSOIL ICE IN ALASKA. (I. C. Russell, *A Journey up the Yukon River*, page 149, and *Second Expedition to Mount Saint Elias*, page 19.)—Professor Russell found ice covered by rocks and vegetation in several places in Alaska, especially along the southern edge of the Malaspina Glacier and on the Yukon River. He gives the following interesting account in 1890 of these ice sheets: "Throughout the length of the Yukon, one is frequently reminded of the high latitude drained by the great river, by seeing strata of ice in the recently cut banks, beneath the dense layer of moss and roots forming the surface on which the forests grow. One may frequently find ice even on a hot summer's day, by scraping away the moss at his feet. In some instances the frozen layer has been penetrated to the depth of twenty-five feet, but its full depth has never been ascertained. In the banks of some of the streams to the north of the lower Yukon, strata of ice over a hundred feet thick have been observed, and the indica-

tions are that its total depth is considerably greater than the portion exposed. This subsoil ice is stagnant and without the characteristics of glaciers."

SUBSOIL ICE IN THE KLONDIKE REGION. (*Philadelphia Ledger*, December 30th, 1897.)—The Klondike mining country is covered with snow most of the year. The ground is frozen for ten or twelve meters in depth, down to bed rock. In some places the ground, which is protected by a thick moss, is not thawed out by the sun in summer. The miner cuts off the moss with a shovel, and then builds a fire, which thaws out the ground for five or ten centimeters. He digs this out, rebuilds a fire, and then continues this process.

ICE CLIFFS ON THE KOWAK RIVER, ALASKA. (Lieutenant J. C. Cantwell, *National Geographic Magazine*, October, 1896.)—On the shores of the Kowak River are a series of ice cliffs of from about 25 meters to 45 meters in height. On top of these ice cliffs is a layer of black silt-like soil some 2 meters in thickness, and from this springs a luxuriant growth of mosses, grass and Arctic shrubbery. The melted ice shows a residuum of fine dust, which while fresh emits a pungent odor.

SUBTERRANEAN ICE SHEET ON KOTZEBUE SOUND. (Otto von Kotzebue, *Entdeckungsreise in die Südsee*, etc. Weimar, 1821. Vol. IV., page 140.)—Dr. Eschholz discovered near Kotzebue Sound, in 1816, a mass of ice more than 30

meters thick, and entirely covered with a layer at least 15 centimeters thick of clay, sand, and earth, on which heavy, long grass was growing. In the ice and in the soil overlaying it, were many remains of extinct animals. On the side towards the ocean the ice was entirely bare, exposed to sun and air, and much of it was melting away in streamlets.

FREEZING LAVA CAVES, WASHINGTON. (R. W. Raymond, *Overland Monthly*, 3d November, 1869, page 421. Th. Kirchhoff, *Reisebilder und Skizzen aus America*, 1876, vol. II., page 211. *Philadelphia Ledger*, September 25th, 1899.)—These caves are distant about four hours from the foot of Mount Adams, and about 56 kilometers from the mouth of the White Salmon River, where it falls into the Columbia River. The caves are in basalt, and they are connected at both ends with the open air. Only a few of them contain any ice, which in the largest cave is about 6 meters below the entrance, from which one descends by a ladder. The cave opens on one side and is some 15 meters in depth, 6 meters or 8 meters in width and 3 meters or 4 meters in height. This part contains the most ice. The other side gradually narrows from the entrance, is longer, and reaches out through fallen rocks and rubbish to daylight. In the lower portion, there are a few ice stalactites and stalagmites: one a superb, transparent hillock, which rises nearly to the roof, is called the Iceberg. A strong draught flows into the cave in summer through the open arm.

The following paragraphs from the *Philadelphia Ledger* probably refer to the same locality :—

"Ice for the cutting, and that in August and early in September, is a novelty not often found in regions as far south as the Columbia River basin; but the novelty is enjoyed every year by people who visit the ice caves under the shadow of Mount Adams, about 100 miles northeast of Portland. It is a very extensive region. Frank McFarland, who has just returned from a six weeks' vacation camping trip there, gives an interesting account of its general make up.

"At the ice caves, which are six miles from Trout Lake, the stalactites are more beautiful and wonderful this year than ever before, and this was Mr. McFarland's fifteenth trip there. He broke off and took to camp chunks of ice weighing 100 pounds. Pleasure parties who come to the lake use considerable of the ice for packing their trout to take home. All you have to do is to take a torch of pitch pine or a lantern, and go into the big caves and pack off all the ice you want. It is a sure crop, and never fails."

Ice Spring in the Rocky Mountains, Oregon. (G. Gibbs, *American Journal of Science and Arts*, 1853, Second Series, vol. XV., page 146.)—The Ice Spring is about 60 kilometers from the South Pass to the right of the Sweetwater River. It is situated in a low marshy swale, where the ground is filled with springs; and about 60 centimeters below the turf is a sheet of horizontal ice, some 10 centimeters to 30 centimeters thick, lasting throughout the

year. The ice is clear and is disposed in hexagonal prisms; it has a slightly saline taste, the ground above it being impregnated with salt and the water near by tasting of sulphur.

FREEZING LAVA CAVES IN MODOC COUNTY, CALIFORNIA. (*Dispatch*, Frankford, Pennsylvania, 22d January, 1897, reprinted from another paper.)—The lava beds, where the Modoc Indians made their last stand against the United States troops, are described as an immense field of lava covered with a beautiful forest of conifers. Numerous caves of varying shapes and dimensions are scattered throughout these lava beds. Some are mere covert ways, with an arch of stone thrown over them; others are immense chambers some meters from the surface; another kind sinks deeply and may be in a series of chambers united by a corridor that opens at the surface; while another kind seems to go directly to the centre of the earth without stopping. Some of these caves contain ice and from them the Modocs drew their water supply while besieged by the troops. Judging from what is reported of the caves the quantity of ice in them must be large. The thermometer in winter in the region is said to go as low as — 30° C.

FREEZING LAVA BEDS NEAR MEDICINE LAKE, SISKIYOU COUNTY, NORTHERN CALIFORNIA. (M. S. Baker, *Sierra Club Bulletin*, 1899. Vol. II., page 318.)—"One other feature of the lava region must be mentioned—the ice caves.

There are several of these known, and very likely many more remain undiscovered. Those located along the edge of the lava, near the cinder cone, I have known to contain ice and water as late as August. The largest I have seen is on the Mayfield Road, about twenty miles east of Bartles. It is situated in the barren lava, and in one of the warmest localities of the region,—and there are few cool spots in the lava anywhere. One enters the cave by crawling down a hole none too large. The instant the interior is reached the temperature falls in a surprising way. Not more than ten feet below the surface of the hot rocks is a bed of ice, covered by a foot or so of ice water. The body of ice was perhaps twelve or fifteen feet long, by five feet across in the widest places. This cave is formed by a fissure that extends a distance of twenty miles from the ice cave to Pittville, and nearly coincides with the 4000 foot level, as shown in the map. Along the southeastern half of this earth fissure the southwest wall has faulted, leaving a cliff, which, in places, must be nearly 200 feet high."

Freezing Shafts, Montana.—Mr. Robert Butler, of San Jose, Cal., has given me much information about glacières in Montana. He visited one miners' shaft which is situated about 80 kilometers up the Rosebud River from Rosebud Station on the Northern Pacific R. R., and about 10 kilometers northeast of the Cheyenne Indian Agency. It is on the north slope of the Little Wolf Mountains, near the summit, at the head of Greenleaf Creek. The canyon

and surrounding slopes are covered with a dense growth of pine. The rock has the appearance of scoriæ caused by the burning of immense beds of coal in recent geological times. The rock is broken into comparatively small pieces. The altitude is some 1200 meters. The forest, the volcanic ash and the altitude, besides the loose rock formation, makes this place a natural ice house. Ten or twelve years ago three prospectors, looking for silver, sunk a shaft here. At a depth of about 4 meters it began to grow cold, and at 6 meters they found ice and imagined they could feel an upward draught. Being ignorant and superstitious, they became frightened and abandoned the shaft. During the winter, the snow fills the shaft half full of ice, which then remains over through the summer. There is a general report and belief among those who have visited the well, that it freezes in summer and thaws in winter. There are thousands of mining shafts in Montana, and if they are on the north slope of a mountain of considerable altitude and under a dense forest and not too deep, they generally have ice at the bottom during the summer. It is also said to be nothing new for a miner in following crevices to find them filled with ice, especially if near the surface on the north slope of a mountain.

Freezing Cave, Fergus County, Montana.—Mr. Robert Butler, of San José, Cal., visited this place, which is about 35 kilometers southeast of Lewistown. It is on the north side of a butte. Masses of ice and great icicles

form in some parts of the cave in such quantities during the latter part of winter that the cave furnishes ice for cooling the drinking water for several dozen families. During July and August the people come from some distance around to get the ice. The people in the neighborhood believe that the ice forms in summer and thaws away in winter. They also speak of the ever upward draught of cold air coming possibly from some great hidden cavern in the lower recesses of the mountain.

FREEZING WELL AT HORSE PLAINS, MONTANA. (Levi Allen, *Scientific American.* New Series, 27th October, 1883.)—The well is described as 13.60 meters deep. It is dug through solid gravel, and in sinking it there was encountered, at a depth of 10.60 meters, a current of air strong enough to blow out a candle. It began to freeze in September, 1882, and in November it was frozen solid.

FREEZING SILVER MINE, BIGHORN COUNTY, WYOMING.—This place is in the Sunlight Basin of the Shoshone Mountains. Mr. William Worrell Wagner, of Philadelphia, informs me that he visited it in August, 1897. It is a silver mine or tunnel, running straight into the mountain for about 60 meters, at an altitude of about 3300 meters. The peaks of the Teton range were in sight from the mouth of the tunnel. For the first half of the way in, a good many icicles were hanging from the rocks. The last half of the tunnel was thickly coated with ice and looked

like a cold storage plant. Snow disappears on the rocks outside about June, and begins to fall again in September, so that Mr. Wagner's visit was at about the hottest time of the year. Mr. Wagner presented the meat of a bull wapiti he had shot to the miners, and they stored it in the mine as if it had been an artificial refrigerator.

RIFTS OF ICE, MOUNT McCLELLAN, COLORADO. (Edward L. Berthoud, *American Journal of Science and Arts*. Third Series, 1876, vol. XI., page 108.)—Near the summit of Mount McClellan, is the Centennial Lode, which runs into the mountain, at an altitude of about 3900 meters. Intercalated in the mineral vein are three or four well defined veins of solid ice parallel with the bedding of the rock and filling all its inner side-cracks and fissures. The same frozen substratum is found in two other lodes near by on the same mountain. Nothing of the kind is known on other Colorado mountains. The soil is loose and largely made up of rocky débris, which shows that the ice is probably due to local causes.

FREEZING TUNNEL ON THE HAGERMAN PASS, COLORADO. (*Philadelphia Press*, October 16th, 1897.)—The Hagerman Pass Railroad line is said to have been abandoned after the completion of the Busk-Ivanhoe tunnel, but to have been rebuilt. The Hagerman tunnel for a distance of over 700 meters was filled with solid ice, and it required blasting with dynamite, and a month's continuous labor, day and night, to dig the ice out.

FREEZING CAVERN IN COW MOUNTAIN, COLORADO. (*Post Dispatch*, St. Louis, Mo., July 13th, 1897, and September 5th, 1897. *Mail Order Monthly*, St. Paul, Minn., October, 1899.)—The cave was discovered by parties doing assessment work on a group of claims. A man was picking in a three meter hole when he struck his pick into an opening, which was gradually enlarged and showed a deep pit underneath. The men got a rope and descended into an immense cavern full of ice. Later exploration led to a small hall, some 5 meters in diameter, full of icicles. From here a fissure led into a second rock chamber larger than the first. A small hole in the floor at an angle of some 45° gave access to a third and larger hall, about 25 meters by 40 meters. Great masses of ice were found in this, also a small lake, about 12 meters by 20 meters. "Some who have visited the wonderful discovery are of the opinion that it is a great cave or fissure in a glacier which for centuries has been slowly making its way down from Pike's Peak and whose waters are now feeding the Arkansas River."

WINDHOLE, ARIZONA. (*Christian Herald*, March 24th, 1897.)—Mr. Cofman, while drilling a well on his place, is said to have opened a windhole from which the escaping air current was strong enough to blow off the hats of the men who were recovering the lost drill. Some days the air escapes with such force that pebbles the size of peas are thrown up, accompanied by a sound much like the distant bellowing of a fog horn. Again for days there will

be a suction current, unaccompanied by sound, in which the current of air passes into the earth with somewhat less force than when escaping, and any light object, as a feather or a piece of paper, will be immediately sucked in. The account is probably exaggerated.

FREEZING LAVA CAVE NEAR FLAGSTAFF, ARIZONA.—Professor W. B. Scott of Princeton University told me of this cave, which he had not visited himself. It lies 14.5 kilometers south of Flagstaff, on the Mesa table land, at an altitude of about 2000 meters. It was described to Professor Scott as a double cave, with two floors, one over the other, the lower containing the most ice. It is in lava, and can only be entered by crawling in on hands and knees.

FREEZING CAVE OR GORGE, WHITE MOUNTAINS, ARIZONA.—Mr. Frank Hamilton Cushing has told me of this place. It is a cleft among lava rock, which being roofed at the further end, might be described as a cave. In this the ice remains until June or July, much later than anywhere else in the neighborhood. The Zuni Indians worship before this, calling the ice the breath of the Gods, the snow they consider as a sort of down. The region is arid, which makes any water precious, and this fact has developed the element of mysticism about snow and ice among the Indians.

FREEZING CAVE NEAR GALENA, BLACK HILLS, SOUTH DAKOTA. (Miss L. A. Owen, *Cave Regions of the Ozarks*

and Black Hills. Cincinnati, 1898, page 209): "At Galena, a new mining town of golden promise, there is reported to be an Ice Cave, where ice forms at all seasons, and during the warm weather is a source of comfort and pleasure to the miners."

WINDHOLES IN THE OZARK MOUNTAINS, MISSOURI.—Mr. H. F. Brinckerhoff, of Aurora, Mo., informs me that there are a number of cold air current caves in the Ozark Mountain region. One of them is some 19 kilometers south of Aurora, Lawrence County, and is used for cold storage in summer. There is a cave in a limestone bluff about 15 meters above a river, and in the rear is this windhole, which is an opening about 30 centimeters high and 3 meters wide. A strong current of air comes out from it in summer, and the hotter the air outside, the stronger is the outward coming current. In winter the current is reversed. The outward current is so strong in very hot weather that a handkerchief held in it is straightened out to an angle of about 45°.

FREEZING CAVE AND WELL AT DECORAH, IOWA. Described in Part I. (Dr. C. A. White, *Report of Geological Survey of State of Iowa*, 1870, vol. I., page 80. A. F. Kovarik, *Scientific American Supplement*, No. 1195, November 26th, 1898, pages 19,158, 19,159).

On June 1st, 1869, Dr. White found the ice dry and well frozen, and he thought it was then accumulating. The cave was cool and apparently dry, and no strong air current was passing through.

Mr. Alois F. Kovarik, of the Decorah Institute, has made a valuable series of observations about the Decorah Cave. The temperatures he observed were the following:

	IN THE VALLEY, SHADE.	DIVISION.	LOCUS GLACIALIS.	END.
July 1, 1897	+33.3°	+ 2.2°	0.0°	0.0°
" 27, "	+21.1°	+ 5.0°	0.0°	0.0°
Aug. 14, "	+32.2°	+ 5.8°	+3.1°	0.0°
Sept. 3, "	+32.2°	+ 7.2°	+3.1°	+8.3°
" 18, "	+33.9°	+ 8.6°	+6.1°	+8.3°
Oct. 16, "	+24.0°	+10.0°	+8.3°	+8.3°
" 30, "	+10.0°	+ 7.2°	+4.7°	+5.0°
Dec. 11, "	− 2.2°	− 2.7°	−1.1°	−2.0°
Jan. 8, 1898	− 0.0°	− 2.7°	−3.9°	0.0°
" 22, "	− 5.0°	− 6.1°	−3.9°	−3.9°
Feb. 26, "	− 0.0°	− 6.6°	−6.6°	−5.0°
March 12, "	+ 2.8°	− 1.6°	−2.7°	−2.7°
" 26, "	+ 8.8°	− 1.7°	−1.6°	−1.1°
April 16, "	+25.6°	− 1.4°	+1.1°	−1.1°
" 30, "	+13.9°	+ 1.1°	−1.1°	−1.1°
May 28, "	+17.2°	+ 1.7°	−0.3°	0.0°
June 9, "	+25.0°	+ 1.7°	−0.3°	0.0°
" 18, "	+22.3°	+ 1.7°	−0.2°	0.0°
July 16, "	+35.0°	+ 7.2°	0.0°	+2.2°

On the 1st of July, 1897, a cold breeze was noticed coming from the cave to a distance of at least 30 meters. At the entrance the breeze was strong enough to blow out a candle. This breeze was not noticed at other times. From December to February inclusive, on the contrary, the breeze was reversed. From July to October, 1897, the walls of the cave were moist. From October to February they were dry. In February frost began to

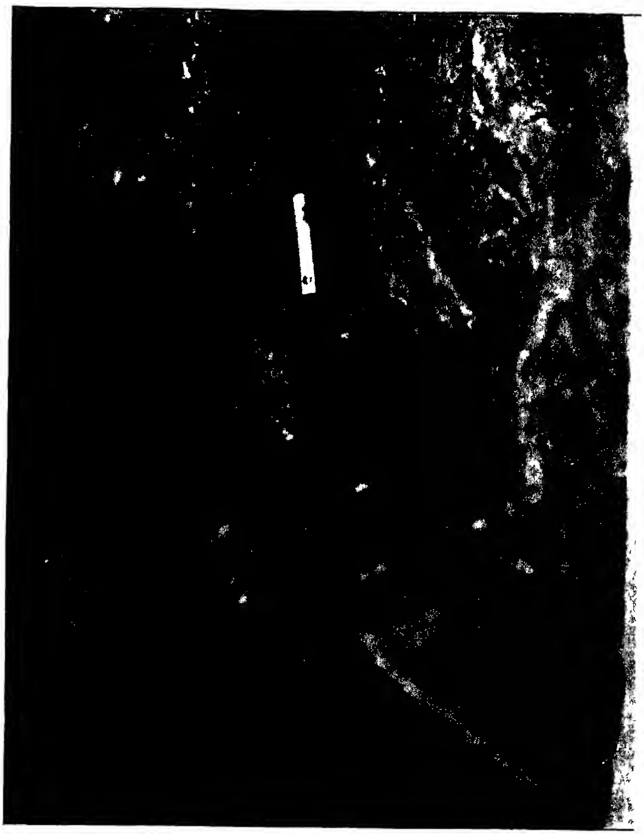
appear on the walls. On March 12th, 1898, the walls were covered with frost. The ice appeared at a spot nearly at the end of the cave on the 26th of March, 1898. At a place about 6.50 meters nearer the entrance, however, is where most ice forms. This place Mr. Kovarik calls *Locus Glacialis*. The ice appeared here about the 29th of May, 1898. It increased rapidly up to June 12th, when it was at its maximum, and was about two meters in width. It generally covers the north wall from top to base. The greatest thickness in 1898 was 29 centimeters.

The temperature which Mr. Kovarik recorded on the 16th of April at *Locus Glacialis* of + 1.1 seems an anomalous one. On writing to him he sent me the following explanation: "April 16th, after I left the thermometer at *Locus Glacialis* the usual time, I noticed that it registered + 1.1° C. It seemed singular, for at both the Division and the End, the thermometer registered considerably lower. I left the thermometer at its place for about an hour longer, and noticed then that it did not register differently. I would suggest this explanation: This is true about water that upon freezing it gives off its latent heat. Now on April 16th some water dripped into the cave on the wall near where the thermometer was, about 1.50 meters from the floor. The amount of water was very small, but as it came in contact with the cold wall it began to give out its latent heat which affected the close by thermometer. The temperature of the rock was without doubt between — 1.° and — 3°."

FREEZING CAVERN AT BRAINARD, IOWA. (Alois F. Kovarik, *Decorah Public Opinion*, September 20th, 1899.)—This little cave is situated on the north side of a hill about 1.5 kilometers northwest of Brainard. It is about 4.50 meters deep. On June 10th, 1899, Mr. Kovarik found the floor and walls covered with ice. The temperature was 0° C. The owner claims to have taken enough ice out of it on July 4th, 1897, to freeze cream.

FREEZING CAVE NEAR ELKINSVILLE, BROWN COUNTY, INDIANA. (Clipping from a western newspaper, 1896.)—The entrance is said to be overlapped by trees and to resemble a mine shaft. The winding way leads to a hollow some 15 meters below the surface, resembling a broad vaulted corridor, which is known to the natives as the devil's chamber and where the temperature is low. From this point several galleries lead further in, and from one of them comes a blast of icy cold air. This passage is similar to the one at the entrance to the cave, but after a few meters frost is visible, and further on it is thick on all sides, like the crust that is formed on the pipes of an ice plant. The narrow way leads to a big chamber, known as the ice vault. In this dome, which is fully 30 meters in width, the ice forms a large stalagmite and is of unknown depth.

FREEZING GULLY ON MOUNT ABRAHAM, MAINE. (Jackson, *Report of the Geology of Maine*, 1839, III.)—Ice was found in June at an altitude of 1032 meters among the boulders in one of the gullies of Mount Abraham.



FREEZING CAVERN AT BRAINARD

From a Photograph by Mr A F Kovarık.

Subterranean Ice in King's Ravine, Mount Adams, New Hampshire.—Described in Part I., page 1.

Ice Gulch on Crescent Mountain, Randolph, New Hampshire.—Described in Part I., page 83.

Ice in a Hole at Dixville Notch, New Hampshire.—Mr. John Ritchie, Jr., of Boston, has examined this place, which he is sure is a refrigerator. It is in a hole north of the cliff and near its top.

Ice on Mount Garfield, New Hampshire.—Mr. John Ritchie, Jr., informs me that ice was discovered among the boulders on the summit of Mount Garfield during the summer of 1897.

Freezing Talus near Rumney, New Hampshire.—Described in Part I., page 85.

Freezing Talus near North Woodstock, New Hampshire.—Mr. John Ritchie, Jr., has examined this locality. He thinks the ice was gone in July, but judges it to be on the level of an old talus and a couple of meters down.

Freezing Well at Lyman, Grafton County, New Hampshire. (*Geology of Vermont*, 1861, I., page 197.)—A well in that town is reported as having been frozen solid in June, 1816, at a depth of about 2.60 meters from the surface.

Icy Wells at the Foot of Mount Mansfield, Vermont. (N. M. Lowe, *Science Observer*, vol. II., page 58.)—These are described as being really "incipient caves."

Freezing Cave near Manchester, Vermont.—Described in Part I., page 76.

Ice Bed of Wallingford, Rutland County, Vermont. Described in Part I., page 99. (S. Pearl Lathrop, *American Journal of Science and Arts*, 1844, XLVI., page 331.)—Dr. Lathrop says that ice has been found at the Ice Bed as late as September.

Freezing Wells at Brandon, Vermont. Described in Part I., page 77. (*Geology of Vermont*, 1861, vol. I., page 192.)—Mr. Hager says that the well was dug into a mass of sand and gravel, of the kind known as modified drift. The gravel was frozen at the time of digging. The Boston Natural History Society, in 1859, sank two wells, one 21 meters southeast of the original one, the other 21 meters northwest. The first was 10 meters in depth and did not reach ice; the second was 11 meters in depth, and came to the layer of frozen gravel.

Cave near Brandon, Vermont. (*Geology of Vermont*, 1861, vol. I., page 197.)—Mr. Hager heard that about 3 kilometers north of Brandon village was a cavern, in a hill, in which ice is found most of the summer.

Icy Gulf near Great Barrington, Massachusetts.—Mentioned in Part I., page 99.

Icy Glen near Stockbridge, Massachusetts.—Described in Part I., page 75.

The Snow Hole, New York: near Williamstown, Massachusetts. Described in Part I., page 98. (Dewey, *American Journal of Science and Arts*, 1819, vol. I., page 340; and 1822, vol. V., page 398.)—Mr. Dewey found, in June, snow 2 meters deep on ice of unknown depth. On his second visit he found less ice and snow than on his first visit, as the trees in the neighborhood had been cut down.

Glacière near Williamstown, Massachusetts.—Described in Part I., page 101.

Freezing Well near Ware, Massachusetts.—(*Geology of Vermont*, 1861, vol. I., page 197.)—Depth 11.5 meters. This is in a sand and gravel formation much like that at Brandon, except that there is less clay, and that none of the pebbles are limestone.

Wolfshollow near Salisbury, Connecticut. (C. A. Lee, *American Journal of Science and Arts*, 1824, vol. VIII., page 254.)—In the eastern portion of the township, at an altitude of about 800 meters, is a chasm about 100 meters long, 18 meters deep and 12 meters wide. It is in mica-slate, and is sheltered by large trees. At the bottom at one end is a spring of cold water and a cave of considerable extent, in which ice and snow is found the greater part of the year.

Natural Ice House, near Meriden, Connecticut. (Benjamin Silliman, *American Journal of Science and Arts*, 1822, vol. IV., page 174.)—It lies between New Haven and Hartford, about 32 kilometers from the sea, at an altitude of about 60 meters. The ice is found in a narrow defile of perpendicular trap rock, at the bottom filled with broken stones. The defile is so placed that in summer the sun only shines into it for about an hour each day; it is also well protected by surrounding trees, the leaves from which form beds at the bottom among the rocks and help to protect the ice.

Natural Ice House of Northford, Connecticut. (Benjamin Silliman, *American Journal of Science and Arts*, 1822, vol. IV., page 177.)—About 11 kilometers from New Haven on the Middletown road between Branford and Northford, is a gorge where ice remains throughout the year. In this case the ice is mixed with a considerable quantity of leaves and dirt; it has sometimes been brought to New Haven.

Ice in an Old Iron Mine, near Port Henry, Lake Champlain. (*Geology of Vermont*, 1861, vol. I., page 199.)—Ice was found during the summer at a depth of from 15 meters to 30 meters, and a current of cold air was issuing from the opening. There seems to be more than one opening to the mine.

Freezing Talus on Lower Ausable Pond, Essex County, New York.—Described in Part I., page 79.

Freezing Talus at the South Base of the Giant of the Valley, Essex County, New York.—Described in Part I., page 81.

Freezing Boulder Talus, Indian Pass, New York. See Part I., page 83.

Freezing Boulder Talus, Avalanche Pass, New York.—See Part I., page 83.

Freezing Cave near Carlisle, New York.—See Part I., page 93.

Ice among the Catskill Mountains, New York.—Mr. George Brinton Phillips informs me that he has seen subterranean ice in August among boulders in a gorge in the Catskills near the Stony Cloves road, starting out from Haines' Falls. The people in the neighborhood speak of the place as an ice cave.

Gorge in the Shawangunk Mountains, near Ellenville, Ulster County, New York. Described in Part I., page 91. (Heilprin, *Around the World*, 1894, page 194.)—Professor Heilprin found in July a mass of ice measuring about thirty meters in length and 1 meter in depth. The thermometer near the ice read about 1° C. above freezing point, the day being hot. Icicles hung from the ledges on the side of the gorge.

Freezing Gorge at Sam's Point, New York.—See Part I., page 93.

Ice Deposits and Windholes at Watertown, New York.—Described in Part I., page 86.

Freezing Well near Tioga, New York.—Depth, 23 meters. No information.

Freezing Well near Prattsburg, New York.—Depth, 6.5 meters. No information.

Freezing Well near Owego, New York. Described in Part I., page 74. (D. O. Macomber, *American Journal of Arts and Sciences*, 1839, vol. XXXVI., page 184. *Well's Annual of Scientific Discovery*, 1856, page 190.)—The thermometer is said to have stood at —1.2° at the bottom of the biggest well when it registered —20° outside. When a candle was let down, the flame became agitated and was thrown in one direction at the depth of 9 meters; at the bottom the flame was still, but soon died out. Large masses of ice were found in the biggest well as late as July, and the men who made the well were forced to put on thick clothing in June, and even so could not work for more than two hours at a time.

Cave in the Panama Rocks, Chautauqua, New York. The Rev. Horace C. Hovey informs me that he has been in a small cave in this locality, and that he found ice in it.

Cave in Sussex County, New Jersey.—A clipping from a newspaper, with neither name nor date, says that new ice is found daily on the land of Peter Feather, in the mouth of an unexplored cavern. A small stream of water

runs out of the cavern and forms a pool at the opening, and here it is that the ice forms. Enough has been taken in one day to freeze two cans of ice cream. A cold draught of air issues continuously from the cavern.

Hole Containing Ice on Blue Mountain, New Jersey. Reported; no information.

Gorge Containing Ice on Bald Eagle Mountain, Clinton County, Pennsylvania.—Mr. Henry Chapman Mercer, of Doylestown, learned of the existence of this gorge during the summer of 1897. It is near the village of McElhatten, in the neighborhood of Lock Haven, and is some 3 kilometers distant from the Susquehanna River. Ice is said to remain over during the entire summer.

Freezing Cave and Windholes near Farrandsville, Clinton County, Pennsylvania.—Described in Part I., page 93.

Underground Ice Formations, Sullivan County, Pennsylvania, on the southwestern borders of Lycoming County.—Mr. W. Coleman Hall of Philadelphia, about twenty years ago, found ice in two or three places, on Bear Creek, north of Muncy Creek, about 25 kilometers north of the Susquehanna River, and southwest of Eagles Mere. The ice was under rocks, in what may be described as limestone sinks. Since the destruction of the forest, the ice has become less abundant, if indeed any still forms.

GLACIÈRES IN ABANDONED COAL MINES NEAR SUMMIT, CARBON COUNTY, PENNSYLVANIA.—Described in Part I., page 95.

ICE CAVE RAILROAD STATION, LUZERNE COUNTY, PENNSYLVANIA. On the Bowman Creek branch of the Lehigh Valley R. R.—Mr. F. Holschuh, agent at Luzerne, informs me that about 2 kilometers from Ice Cave Station is a little waterfall on the side of a mountain which was formerly covered with dense forest. A short distance below the fall, a large hollow place has been worn out of the rocks by the action of the water. The overhanging rocks give this almost the appearance of a cave. While the forest was still thick and when the winter was cold, ice would form under these rocks and would not disappear until summer was well advanced. The station was called Ice Cave on account of this place.

HOLE CONTAINING ICE AT MILLERSTOWN, PENNSYLVANIA.—Reported; no information.

FREEZING TALUS AT SPRUCE CREEK, HUNTINGDON COUNTY, PENNSYLVANIA. Described in Part I., page 90. The *Philadelphia Ledger* of July 6th, 1896, states that around the boulders where the ice lies, there are found varieties of plants strongly arctic in character.

ICE MOUNTAIN, HAMPSHIRE COUNTY, VIRGINIA. (C. B. Hayden, *American Journal of Science and Arts*, 1843,

vol. XLV., page 78.)—It lies on the North River, near the road leading from Winchester to Romney, at an altitude of from about 220 meters to 240 meters. One side of the hill is entirely composed of loose stones, among which an abundance of ice is found at all times, although the sun shines on the upper surface of the stones from ten in the morning until sunset. The ice is regularly used in summer by the people near by. Constant and strong air currents issue from the crevices in the rocks. Similar, but smaller accumulations, are said to occur in the same county. Mrs. George B. Balch visited the Ice Mountain in August, 1878. She saw no ice, but the air under the stones was very cold.

BLOWING CAVE, BATH COUNTY, VIRGINIA.—Mrs. Horace Jayne informs me that there is a blowing cave near the Cowpasture River, about half way on the old stage road between Millboro and Warm Springs. A draught flows out from it, strong enough to blow the grass about, three or four meters away. The draught is cold, perhaps abnormally so. The cave has not yet been explored.

SOUTH AMERICA.

ICE SHEETS ON MOUNT CHIMBORAZO. (A. von Humboldt, *Travels to the Equinoctial Regions*, London, 1814, vol. I., page 156.)—"On Chimborazo, enormous heaps of ice are found covered with sand, and in the same manner as at the Peak [of Teneriffe] far below the inferior limit of the perpetual snows."

TIERRA DEL FUEGO. (A. Winchel, *Walks and Talks*, 1898, page 122.)—"On Tierra del Fuego ice and lava are found interstratified for a great depth, each winter's snow being covered by a new lava sheet."

TENERIFFE.

LA CUEVA DE LA NIEVE OR DEL HIELO. (Humboldt, *Travels to the Equinoctial Regions*, 1814, vol. I., pages 154, 156. C. Piazzi Smyth, *Teneriffe, an Astronomer's Experiment*, 1858, page 348.)—La Cueva de la Nieve lies at an altitude of 3267 meters in the Malpays on the Peak of Teneriffe, just below the snow line. It is in obsidian. The entrance is 3.6 meters high and 2.7 meters broad. The grotto is 36 meters long, 6 meters wide, and 4 meters high. The descent into the cave is so steep that it is necessary to be lowered by ropes. Professor Smyth found in July an ice floor about 60 centimeters thick which was covered with water. A good deal of snow was lying near the mouth of the cave. The walls were covered with ice and icicles and a few small ice cones rose on the ice floor.

ICELAND.

THE SURTSHELLIR OR CAVE OF SURTUR. (Olafsen and Povelsen, *Voyage en Islande*, Paris, 1802. Henderson, *Iceland*, 1819, 2d ed., page 420. Guimard, *Voyage en Islande*, page 481.)—The Surtshellir lies in the volcanic waste of Westisland, and is in lava which has flowed from the Bald Jokul. The approach is through an open chasm.

The length of the cave is 1534 meters, with an average width of from 15 meters to 17 meters, and a nearly uniform height of from 9 meters to 11 meters. In four places the roof is broken and allows daylight to enter. A great deal of ice is sometimes found in the cave, in the shape of an ice floor, transparent icy pillars, hanging icy pendants, and columns and arches of ice along the walls. Some of the pillars have been found 2.50 meters high.

KUTLAGAYA. (A. Winchel, *Walks and Talks*, 1898, page 122.)—"In 1860 the crater of the mountain Kutlagaya, in Iceland, hurled out simultaneously into the air lumps of lava and ice, all intermingled together."

SCANDINAVIA.

ICE IN THE MINES OF NORDMARK. (Jars, *Voyages Métallurgiques*, 1774, page 105.)—13 kilometers north of Philipstadt, Wermeland, Sweden, a number of holes were dug, some to a depth of 120 meters. Ice of some thickness formed in some of these towards the end of winter, and lasted until about September, despite the fires of the workmen.

PERSBERG IRON MINES, SWEDEN. (J. Prestwich, *Collected papers*, etc., on page 206, quotes Dr. Clark's *Travels in Scandinavia.*)—Ice is said to have been found on the sides and bottom of the mine to a depth of about 135 meters.

Ice Caves Reported in Norway.—I was told in Norway that some of the caves in the mountains near the Swartisen ice field contained ice, but I do not know whether this is true. I suspect that there are glacier ice caves which have given rise to this report.

ENGLAND.

Helvellyn, Cumberland. (Wordsworth, *Fidelity*.)—The following verses were pointed out to me by Mr. Bunford Samuel. As far as I know they are the only poetry about glacières :—

> "It was a cove, a huge recess
> That keeps, till June, December's snow;
> A lofty precipice in front,
> A silent tarn below!
> Far in the bosom of Helvellyn,
> Remote from public road or dwelling
> Pathway or cultivated land
> From trace of human foot or hand."

Ice in an Old Copper Mine, Cumberland. (J. Clifford Ward, *Nature*, vol. XI., page 310.)—Ice reported as a rare occurrence.

Ludchurch Chasm, Staffordshire. (R. K. Dent and Joseph Hill's *Historic Staffordshire*, quote Dr. Plot, 1686.)—Mr. Bunford Samuel called my attention to this book, in which Dr. Plot is quoted as saying that as late as the 17th of July, snow has been found in Ludchurch Chasm. Messrs. Dent and Hill do not mention anything of the kind as occurring now.

Blowing Cave in Denbighshire, Wales.—A newspaper cutting says that there are such strong eruptions of winds from a cave in this neighborhood as to toss back to a great height in the air any article of apparel thrown in.

Tin Croft Mine, Cornwall. (J. Prestwich, *Collected papers*, etc., page 206, quotes Mr. Moyle.)—Ice has been found in abundance in this mine at a depth of nearly 100 meters.

CENTRAL EUROPE.

Glacière de Chaux-les-Passavant. Described in Part I., page 8. (Poissenot, *Nouvelles Histoires Tragiques de Benigne Poissenot, licencié aux lois. A Paris, chez Guillaume Bichon, rue S. Jacques, a l'enseigne du Bichot, 1586, avec privilege du Roy*, pages 436–453. Gollut, *Les Memoires historiques de la Repub. Sequanoise, et des princes de la Franche Comte de Bourgogne, par M. Lois Gollut, Advocat au Parlement de Dôle; A Dôle, 1592.* Trouillet, *Mémoires de la Société d'Emulation du Doubs, 1885.* Girardot, *Mémoires de la Société d'Emulation du Doubs*, 1886.)

The earliest notice of a glacière which I have been able to find is in the shape of a letter giving an account of a visit to the Glacière de Chaux-les-Passavant in 1584, by Benigne Poissenot, a French lawyer. The account, which I have translated as literally as possible, is in a special chapter, as follows:—

"Sir:—Since our separation, I have had this pleasure (*heut*) to hear news of you only once, having found

your brother in Paris; who, having assured me of your good health (*disposition*), informed me of how since we had seen each other you had travelled to Italy, even as far as Greece, of which you had seen a large portion: and that sound and safe, after so long a journey, you had reappeared and landed at Havre de Grace where you wished to go, that is to say at home. All the pleasure which a friend can receive, knowing the affairs of another self, joined to such a happy result, seized my heart, at the recital of such agreeable news: and I did not fail shortly after, to write you amply all which had happened to me since I left you until my return to France: congratulating you at having escaped from marine abysses and perilous passages on land, on which travellers are often constrained to risk their life. From this time, I have always stayed in Paris or in the neighborhood, according to the good pleasure of dame fortune, who ruled me in her wise and fed me with her dishes the most common and ordinary until the first day of January of the year 1584, when I received my first gift in the shape of a strong and violent disease, which tormented me more than a month: from which, having become cured with the help of God, and having with time recovered my health and my strength at the arrival of spring, I was seized with the desire to smell the air of the country. And in fact having thrown away my pen and travelled about (*battu l'estrade*) through high and low Burgundy, I stopped at Bezenson, Imperial City, to spend the summer. This city is still to day

just the same as Julius Cæsar describes it, in the notable mention he makes of it, in the first book of his commentaries of the war in Gaul, there remaining there all the vestiges of the most remarkable things, which he tells of in his description. There are also very fine fountains, from all of which water streams from the representation of some god of antiquity, as a Neptune, a Bacchus, a Pan, a Nereide or others: except before the state house, where the statue of Charles the Fifth, representing him in a most natural manner, is placed on an eagle, which from its beak, pours out such a great quantity of water that this is the most beautiful, among all the other fountains. And as I do not doubt that while traversing Italy, you both saw and examined with curiosity the most handsome singularities, which presented themselves to your eyes and that on your return, passing through Avignon and Dauphine, as your brother informed me, you had the advantage over me of seeing the wonders of the country, of which you had heard me speak sometimes, regretting that the war, during the time I was in that quarter, had prevented my going to the spot, to see the burning fountain as in Dodone, and the fountain called Jupiter, which torches of fire light up and which grows less till midday and then grows till midnight, and then diminishes and fails at midday: and another in Epirus which we call to day Albania, the tower without venom and the inaccessible mountain: then as I said, since you have contemplated these things and several others not less admirable, I wish to entertain you about a marvel which

I saw, during my sojourn in Bezenson, to know from you, whether in all your journey, you saw a similar thing. Know then that the day of the festival of St. John Baptist, a young man, provided with an honest knowledge, with whom I had made some little acquaintance, presented me with an icicle, to cool my wine at dinner, and which I admired greatly, on account of the time of the year in which we then were, begging him who gave it to me to tell me where he had discovered this rare present for that time. He answered me that every year, the day of the solemnity of the festival of St. John Baptist, the inhabitants of a village, which he named, were bound to come to offer the great church of St. John of Bezenson, a goodly quantity of ice, which they got in a wood, and brought to town at night on horses, for fear that by day it should melt, and that one of his cronies had given to him what he had given to me.

"Suddenly there flamed up in me a desire to see this place, where in the height of the summer, ice was to be found. When he who had presented me with the icicle saw this, he promised to accompany me, not having as yet, any more than myself, seen this marvel. I did not hatch very long this decision, all the more as all those, to whom I mentioned it, encouraged me to carry it out as soon as I could, assuring me that I should see a strange thing, and that even the Duke of Alva on his return from Flanders, passing through Franche Comté, had wished to see this novelty. Therefore calling on the promise of the one who was the cause of undertaking this journey, we went

together to Versey, a fine town, distant five leagues from Bezenson, turning a little off our direct route, to go to see a literary man, at this said Versey, who having called on me at Bezenson, had extracted from me the promise of going to see him. There happened to me in this spot, what the poet du Bellay says happened to him, on his return from Italy, passing through the Grisons, to go into France: who, after having chanted the troubles there are in the passage, says that the Swiss made him drink so much, that he does not remember anything he saw in that country. Likewise, I can assure you that my host, following the custom of those of the country (who do not think they are treating a man properly if they do not make him drink a lot, taking that from the Germans, their neighbors) made us carouse so well, that when we went to bed, we were very gay boys. For although we had both made an agreement on the road, yet our host knew so well how to win us over, saying that those who would not drink, gave reason to think badly of them, and that they had committed, or wished to commit some great crime, which they feared to give away in drinking, that in the end we let ourselves go, passing the time in Pantagruelic fashion. The next morning having taken some "hair from the beast" and a guide which our host gave to us to conduct us to the *Froidiere*—we continued our wanderings, and arrived at a little village called Chaud, joining a large wood, where our guide told us, that although he had been more than six times to the *Froidiere*, yet the road was so tortuous and so cut up by small paths, that if we did not

take a man from this village, to be more sure, we might spend more than half a day in the wood, before finding what we were seeking. Getting off our horses now, we added to our company a native of the place, who having led us by crooked roads, about a quarter of a league, through the forest, made us enter into a close thicket and by a little path led us to a pleasant meadow; where, looking down, we saw a hole, of difficult descent, at the bottom of which was the opening of a grotto, pretty big, and so awful and terrifying to see, that one would have said, it was the mouth of Hell. And in truth, I remembered then, the hole of St. Patrick, which is said to be in Hibernia. We were not brave enough knights, to try the adventure, my companion and I, if our guides had not taken the lead. After whom we descended as magnanimously as the Trojan Duke followed the Sybil to the Plutonic realms, the sword half drawn from the scabbard, and well determined to make test of the Platonic doctrine, which teaches that demons can be dissected, in case any shade or spook should have come to meet us. About the middle of the way, we began to feel in descending a very agreeable freshness; for it was the second day of July and the sun shone very warmly, which made us sweat drop by drop. But we had good opportunity to refresh ourselves and put ourselves to cool, having reached the grotto which we found of the length and breadth of a large hall, all paved with ice in the bottom, and where a crystalline water, colder than that of the mountains of Arcadia Nonacris, streamed from many small brooklets, which formed very

clear fountains, with the water of which I washed myself and drank so eagerly, that I had wished the thirst of Tantalus, or else that I had been bitten by a Dipsas, in order to be always thirsty, amid such a pleasant beverage. A great lord, who in some pleasure resort, should have such a refrigerator in summer, could boast according to my judgment, to be better provided with drink, than the kings of Persia were with their river Coaspis, which engulphs itself into the Tigris, the water whereof was so sweet, that the use of it was allowed only to the great King, for the retinue and cronies of his household. Do not think, that among these delights, I was at all free from fear, for never did I raise my eyes above that from terror my whole body shivered and the hair stood up on my head, seeing the whole roof of the grotto, covered with big massive icicles, the least of which, falling on me, had been sufficient to scramble up my brains and knock me to pieces; so much so that I was like to that criminal, whom they say is punished in Hell, by the continual fear of a big stone, which seems as though it must suddenly fall on his ears. There are besides the large hall of the grotto, some rather roomy corners, where the gentlemen of the neighborhood, put their venison to cool in summer, and we saw the hooks, where they hang the wild fowl. It is true, that when we were there, we saw neither game nor wild fowl, and I think, that if we had found any of it, we were men to carry off some of it. We walked around for about a quarter of an hour, in this *Froidiere* and we should have staid there longer if the cold had not driven us out; which

struck in to our backs, even to make our teeth crack; we reascended the slope, not forgetting, all of us as many as we were, to provide and load ourselves with ice, which served us at lunch in the little village mentioned above to drink most delightfully, assuring you that it is impossible to drink more freshly than we drank then. I thought of those old voluptuaries, who cooled their wine with snow, and it seemed to me, as though they might have had it much cheaper if in their time there had been many such *Froidieres*, to refresh it with ice, instead of with snow, as some of the gentlemen of the neighborhood of the *Froidiere* and some of the most notable persons of the neighborhood of Bezenson do; who by night, have a good supply brought on horses, which they keep in their caves, and use at their meals and banquets. Turning back towards the Imperial city of Bezenson, I carried for about two great leagues, a rather large icicle in my hands, which little by little melted and was a pleasant and agreeable cooler, on account of the great heat of the weather. After having thought over in my mind, the cause of this *antiperistase*, I could find none other but this: to wit, that as heat domineers in summer, the cold retires to places low and subterranean, such as is this one, to which the rays of the sun cannot approach, and that in such an aquatic and humid place, it operates the results, which we have shown above. Which seemed to me so much more likely, that on asking the peasants of the neighboring village, if in winter there was ice in this *Froidiere*, they answered me that there was none, and that on the contrary, it was very

warm there. Whatever may be the cause, whether this or another, I can assure you, that I admired this singularity as much as any I have seen, since a large church, cut into a rock which I had seen a few years previously, in a little town of Gascony called St. Milion, distant seven leagues from Bordeaux; on the steeple of which is the cemetery, where they bury the dead; a thing to be marvelled at by him who has not seen it.

"I have made trial, to enrich this missive, with all the artifice which has come into my head, using the leisure, which the present time brings me: as the temple of Janus is open, the air beyond breathing nothing but war: which forces me, against my wish, to sojourn in this place longer than I had intended. If these troubles settle down, and if after the rain, God sends us fine weather as requires the calamitous state in which is now the flat country, I shall return to my Parnassus; from which if I go out hereafter, believe that it will be very much in spite of myself, or that my will will have very much changed. You will be able to let me hear from you there, and take your revenge for the prolixity of this letter, by sending me one still longer, which you will write to me with more pleasure, as I shall take much in reading it. However as it is becoming time to sound taps, I will pray the sovereign creator for my affectionate recommendations to your graces.

"Sir, and best friend, may you keep in health and have a long and happy life. From Sens this 20th of June 1585.

"Your obedient friend BENIGNE POISSENOT.

"End of the description of the marvel, called the *Froidiere.*"

The next notice about the Glacière de Chaux-les-Passavant is by Gollut in 1592, as follows:—

"Ices in summer."

"I do not wish however to omit (since I am in these waters) to bring to mind the commodity, which nature has given to some dainty men, since at the bottom of a mountain of Leugné ice is found in summer, for the pleasure of those who wish to drink cool. Nevertheless at this time, this is disappearing, for no other reason (as I think) except, that they have despoiled the top of the mountain, of a thick and high mass of woods, which did not permit that the rays of the sun came to warm the earth, and dry up the distillations, which slipped down to the lowest and coldest part of the mountain where (*by antiperistase*) the cold got thicker, and contracted itself against the heats surrounding and in the neighborhood during the whole summer, all the external circumference of the mountain."

The ice at Chaux-les-Passavant is said to have been entirely cleared out, by the Duc de Lévi, in 1727, for the use of the Army of the Saone. In 1743, when de Cossigny visited the cave, the ice was formed again. There are no reports about the intervening time between 1727 and 1743. The ice probably all re-formed the winter after it was taken away.

Captain Trouillet in 1885 writes of Chaux-les-Passavant: "The following winter had shown itself unfavor-

able to the production of ice, the periods of humidity preceding too long ahead the periods of frost. Finally last summer, coming after a wet spring, was exceptionally warm. Such were the circumstances which brought about in the glacière the ruin which could be seen at the end of last October. * * * On the 11th of November, the first effects of frost are felt and the temperature falls in the glacière to —2°: outside the thermometer drops to —3°. On the morning of the 12th, same result, and ice makes its appearance in the grotto, as the report of the observer shows: but the quantity produced is so small that the internal thermometer soon goes above 0°. It is only on the 9th of December that the frost wins definitely; on the 11th, 12th and 13th the chill is intense and reaches —19° outside, stopping at —15° in the glacière. The water coming from the rains between the 5th and the 9th drip at this time through the roof and the big side crevasse: circumstances grow favorable and the ice accumulates. From the 17th, the entrance slope becomes almost impracticable; the icicles grow on the roof, as big as the body of a man. * * * From this time to the end of December, the ice sheet does not increase, for water only arrives by the rare drip of the roof, and only the stalactites increase slowly. Outside, however, the cold continues vigorously, the thermometer on the 31st of December dropping to —15° and to —13° in the glacière. If the production of the ice stops, it is not the cold which is wanting, but the other element, the one which as our former study showed, is the most rarely exact at the

meeting. The winter is only favorable on condition that it offers alternating periods of freezing and thawing; so the observer writes in his report: 'it is the water which is wanting, otherwise the glacière would be magnificent.' "

Trouillet speaks of the difficulty of winter observations in the following words: " Mons. Briot, the present lessor of the glacière, has the unpaid mission of going every week to the bottom of the grotto to get and put in place the interior thermometer. It is a really hard piece of work at this time of the year: each journey takes about one hour. Besides the chance that a visitor has of receiving on his head one of those magnificent stalactites 1 meter or 2 meters long which fall continually from the roof, it is perfectly disagreeable to him to arrive at the base of the slope otherwise than on the sole of his boots, and to face thus the frequent and painful meeting with rocks whose angular edges dot the surface of the descent, smooth as a mirror set at an angle of 30°."

Trouillet and Girardot obtained a series of observations with maxima and minima thermometers at Chaux-les-Passavant during the winter of 1885–1886. At the end of November the temperature inside was + 2°. On the 2d of December it rose to + 2.5°. On the 10th of December, it sank to — 1°, and after this date, it remained below freezing point all winter. The observations were not continuous, but they showed that every time the temperature outside dropped considerably, the temperature inside immediately did likewise. For instance, on the 12th of January, the outside air dropped

to —18°, and the inside air responded by falling to —15°. On the other hand, when the temperature outside rose above freezing point, the temperature inside remained stationary or fluctuated only gently. For instance, from the 24th of March to the 8th of April, the outside air went up and down perpetually, the extremes being —2° and +16°; while in the same time the inside air rose continuously from —2° to —0.5°.

WINDHOLES AND ICE FORMATIONS NEAR GÉRARDMER, VOSGES. (Rozet, in *Encyclopédie Moderne*, Didot Frères, Paris, 1853, vol. XVI., page 503.)

L'ABIME DU CREUX-PERCÉ OR GLACIÈRE DE PASQUES. (Martel, *Les Abimes*, 1894, page 394; *Annuaire du Club Alpin Français*, vol. XIX., page 38.)—On the plateau of Langres, Côte d'Or. It lies 15 kilometers from Dijon, and is really a limestone rock gorge, of 55 meters in depth, which at the top is 40 meters long and 20 meters wide, and at the bottom is 15 meters long and 12 meters wide. In March 1892, Mons. Martel found the north side covered with large icicles 15 meters long. The ice seems to remain throughout the year. The bottom of the Abime has been reached only by means of two long rope ladders.

CREUX DE CHEVROCHE OR ROCHE CHÈVRE, COTE D'OR. (Clément Drioton, *Mémoires de la Société de Spéléologie*, 1897, vol. I., page 209.)—"In the woods of Mavilly, near Bligny-sur-Ouches, is a little cave, called Creux de

Chevroche or Roche-Chèvre, where one can find ice until the month of July."

FREEZING WELL OF MAROLLES, AT LA FERTÉ-MILON, AISNE. (Martel, *Les Abimes*, page 563, note 2.)—This well is 8.15 meters deep; the altitude is 70 meters. During the winter of 1892–93 the water in it froze for a thickness of 15 centimeters. The minimum outside temperature that year was — 17°.

WINDHOLES NEAR PONTGIBAUD, PUY DE DOME. (G. Poulett-Scrope, *The Geology and Extinct Volcanoes of Central France*, 1858, page 60.)—These windholes are in basalt. There are many cracks, whence cold air currents issue, and where ice has been found, sometimes in summer. There are cold storage huts over some of the cracks.

LE CREUX-DE-SOUCI, PUY DE DOME. (Martel, *Les Abimes*, 1894, page 387.)—This is situated 5 kilometers southeast of Besse-en-Chandesse. It is a large lava cavern with the entrance directly in the middle of the roof. The bottom is partly filled by a lake. The depth from the surface of the ground to the lake is 33 meters; from the smallest part of the opening to the lake the depth is 21.50 meters. Down this last portion one can descend only by means of a rope ladder. The temperature is extremely low; in general near freezing point. In June, July, August and November 1892, Monsieur Berthoule, *maire* of Besse, did not find any snow. On the 10th of August, 1893, on the contrary, he found at the bottom a

heap of snow, which he thinks was formed in the cave itself, by the freezing during their descent of the drops of water which are constantly dripping from the roof. He reports landing on *une montagne de neige, de neige blanche.* On several visits, Mons. Berthoule noticed carbonic acid gas in dangerous quantities. There was none at the time he observed the snow heap, but ten days later he found it impossible to descend into the cave às the carbonic acid gas came up in puffs to the entrance. In the lake, Mons. Berthoule discovered a variety of Rotifer, *Notholca longispina*, and also several algæ and diatoms. The *Asterionella formosa* is the most remarkable from its abundance: it exists in some of the lakes of the Alps, but not in those of the Pyrenees.

AVEN DE LOU CERVI, VAUCLUSE. (Martel, *Les Abimes*, page 563.)—This is a cold cave. It belongs to the class which Mons. Martel calls *avens à rétrécissement*, or *abimes à double orifice.* In September, 1892, Mons. Martel noted a temperature of 6.5° at 53 meters; of 6.8° at 64 meters. Mean temperature of locality, 8.75°.

IGUE DE BIAU, LOT. (Martel, *Les Abimes*, page 304.)—Cold cave. Temperature on 13th July, 1891: 5°.

FOSSE MOBILE, CHARENTE. (Martel, *Les Abimes*, page 380.)—Cold cave. Temperature on 11th April, 1893: 7°.

AVEN DE DEIDOU, CAUSSE MÉJEAN. (Martel, *Les Abimes*, page 223.)—Cold cave. Temperatures on 14th October, 1892: outside air, 4°; at bottom, 6.5°.

AVEN DES OULES, CAUSSE MÉJEAN. (Martel, *Les Abimes*, page 227.)—Cold cave. Temperatures on 21st October, 1892: outside air, 2.5°; at bottom, 4°.

WINDHOLE COLD CAVES NEAR ROQUEFORT, AVEYRON.—They lie 13 kilometers from Millau, at an altitude of about 600 meters, and are utilized in the manufacture of Roquefort cheese.

AVEN DE CARLET, NEAR LA ROCHE GIRON, BASSES ALPES. (Martel, *Les Abimes*, page 53.)—Lumps of ice are reported to have been taken from it.

LA POUJADE, CÉVENNES. (Martel, *Les Abimes*, pages 212–215.)—An intermittent spring in limestone rock. At the bottom of the first gallery, on the 18th of September, 1892, the temperature of the air was 12.3°, and that of a pool of water supplied by drip 11.5°. Mons. Martel thought that the drip brought to the pool the mean annual temperature of the ground through which it had come. A little further within and 5 meters lower, the temperature of the air was 7.3° and that of another pool of water 6.8°. This pool was not supplied by drip and must have been left over by the last flow of the spring. Mons. Martel thought that the lower temperatures at this spot were due to the cold air of winter dropping to the bottom of the cave and on account of its density not being able to get out.

SNOW PRESERVED IN CHASMS IN THE ITALIAN MOUNTAINS. (*The Penny Magazine*, London, August, 1834, page

335.)—Mr. Bunford Samuel called my attention to an article in which the Southern Italians are said to dig wells or cellars on the mountain sides, and to throw snow into them in winter. The snow is well pressed together and straw, dried leaves, etc., is thrown on top. By having a northern exposure for these pits, and seeing that they are in thick forest, or in rifts where the sun does not penetrate, these depots may be safely placed as low down the mountain as the snow falls and lies. Naples is largely supplied [1834] with snow in summer from such snow wells situated on Monte Angelo, the loftiest point of the promontory separating the Bay of Naples from the Bay of Salerno.

COLD CAVES OF SAN MARINO, APENNINES. (De Saussure, *Voyages dans les Alpes*, 1796, III., page 211.)—These are probably windholes.

LA BOCCHE DEI VENTI DI CESI. (De Saussure, *Voyages dans les Alpes*, 1796, III., page 211.)—These windholes were in the cellar of the house of Don Giuseppe Cesi, in the town of Cesi. The cellar acted as a natural refrigerator. The air stream was so strong, that it nearly blew out the torches. In winter the wind rushed into the holes. De Saussure was shown the following Latin verses by the owner:—

> "Abditus hic ludit vario discrimine ventus
> Et faciles miros exhibet aura jocos.
> Nam si bruma riget, quaecumque objeceris haurit.
> Evomit aestivo cum calet igne dies,"

WINDHOLES OR "VENTAROLE" ON MONTE TESTACEO, NEAR ROME. (De Saussure, *Voyages dans les Alpes*, 1796, III., page 209.)—There are a number here among heaps of broken pottery. The temperatures seem abnormally low.

KRYPTA SORANA. (Kircher, *Mundus Subterraneus*, 1664, page 118 and page 239.)—This has been spoken of as a glacière cave, but as there is much doubt in the matter, I quote the passages, on which the reports are based, in the original Latin: "Cryptae sunt naturales, quarum innumerae sunt species, juxta vires naturales iis inditas. Sunt nonnullae medicinali virtute praeditae, quaedam metallicis vaporibus, exhalationibus, aquis scatent, sunt et glaciales, plenae nivibus et crystallo, uti in Monte Sorano me vidisse memini." And further: "Vidi ego in Monte Sorano cryptam veluti glacie incrustatam, ingentibus in fornice hinc inde stiriis dependentibus, e quibus vicini montis accolae pocula aestivo tempore conficiunt, aquae vinoque, quae iis infunduntur, refrigerandis aptissima, extremo rigore in summas bibentium delicias commutato."

SUBTERRANEAN ICE SHEET, MOUNT ETNA, SICILY. (Lyell, *Principles of Geology, 11th Edition*, chapter XXVI.)—This ice sheet is near the Casa Inglese. Sir Charles Lyell ascertained the fact of its existence in 1828, and in 1858 he found the same mass of ice, of unknown extent and thickness, still unmelted. In the beginning of

the winter of 1828, Lyell found the crevices in the interior of the summit of the highest cone of Etna encrusted with thick ice, and in some cases hot vapors actually streaming out between masses of ice and the rugged and steep walls of the crater. Lyell accounts for this ice sheet by the explanation that there must have been a great snow bank in existence at the time of an eruption of the volcano. This deep mass of snow must have been covered at the beginning of the eruption by volcanic sand showered on it, followed by a stream of lava. The sand is a bad conductor of heat and together with the solidified lava, preserved the snow from liquefaction.

GLACIÈRE ON THE MONCODINE. (Fugger, *Eishöhlen*, page 13.)—The Moncodine is described as a Dolomite near the Lago di Como. The cave lies up the Val Sasina, two hours from Cortenuova, at an altitude of 1675 meters. The entrance faces north, and is 2.5 meters high and 1.5 meters wide. The average diameter of the cave is 16 meters. The floor is solid ice, which has been sometimes cut for use in the hotels on the Lago di Como and even been sent to Milan.

LA GHIACCIAIA DEL MONDOLE. (Fugger, *Eishöhlen*, page 8.)—The Mondole is a mountain 2375 meters high, near Mondovi, south of Turin. The cave lies on the eastern slope, at an altitude of about 2000 meters. It is hard to get at. The entrance is to the east, and is 2 meters wide and 1.5 meters high. A passageway some

25 meters long leads to a large chamber where there is plenty of ice. In hot summers ice is brought from the cave to Mondovi. *Ghiacciaia* means freezing cavern in Italian.

La Ghiacciaia del Val Séguret. (Fugger, *Eishöhlen*, page 8.)—It lies near Susa at the base of chalk cliffs, at an altitude of about 1500 meters. The cave is said to be about 40 meters deep, 50 meters wide and 50 meters high. Bonetti in May, 1874, found many icicles and ice cones.

La Borna de la Glace. (Chanoine Carrel, *Bibliothèque Universelle de Genève*, 1841, vol. XXXIV., page 196.)—It lies in the Duchy of Aosta, commune of La Salle, on the northern slope of the hills near Chabauday, in a spot called Plan Agex. The altitude is 1602 meters. The entrance opens to the east and is 60 centimeters wide and 80 centimeters high. One can descend for 4 meters. There are two branches in the rear of the entrance. Chanoine Carrel found an ice pillar 1 meter high in the western branch. He recorded these temperatures on the 15th of July, 1841: Outside +15°. Entrance +2.9°. East branch +0.9°. West branch +0.5°.

Windholes in the Italian Alps. (Fugger, *Eishöhlen*, pages 94–97.)—A number of these seem to have abnormally low temperatures. Some are in the moun-

tains around Chiavenna, and are sometimes, by building small huts over them, utilized as refrigerators. Some are reported in the neighborhood of the Lago di Como near Dongo, near Menaggio, and in the villa Pliniana near Curino; in the neighborhood of the Lake of Lugano at e base of Monte Caprino, near Melide, near Mendrisio and near Sertellino; and in the Val Maggia near Cevio.

THE GLACIÈRE DE FONT D'URLE, OR FONDURLE, DAUPHINÉ. (Héricart de Thury, *Annales des Mines*, vol. XXXIII., page 157; G. F. Browne, *Ice Caves*, etc., page 212; E. A. Martel, *Mémoires de la Societé de Spéléologie*, vol. I., page 37; L. Villard, *Spelunca*, 1896, vol. II., page 39.)—It lies on the Foire de Font d'Urle, 16 kilometers north of Dié, 48 kilometers east of Valence, and 80 kilometers south of Grenoble. The glacière consists of two large pits, lying east and west, and with underground communication. From this tunnel a long low archway leads to a broad slope of chaotic blocks of stone, which is 60 meters long and 42 meters in greatest width. The ice begins half way down this slope, fitfully at first and afterwards in a tolerably continuous sheet. Thury found many icicles hanging from the roof. Browne found four columns of ice, of which the largest was 5.80 meters across the base. On his visit, in the middle of August, the ice was strongly thawing. Both explorers noted the extremely prismatic character of the ice. Browne found a temperature of $+0.5°$. Martel gives a section and plan

of Font d'Urle. Mons. Villard says about this cavern: "A curious thing: I found in this cave, motionless on a piece of rock, entirely surrounded by ice for a distance of several meters, a blind specimen of a coleoptera, *cytodromus dapsoïdes.*"

THE CHOURUN CLOT. (E. A. Martel, *Sous Terre. Annuaire du Club Alpin Français*, vol. XXIII., 1896, pages 42, 43; *Mémoires de la Société de Spéleologie*, vol. I., page 31.)—In Dauphiné, half way between Agnières and the Pic Costebelle, at an altitude of 1,740 meters. There is first a pit 18 meters long, 4.50 meters wide and 25 meters deep. In the bottom of this is a vertical hole 15 meters deep and from 1 meter to 2 meters in diameter, in which there was much ice on the 31st of July, 1896. Then the pit changes to a sloping gallery which terminates in a little hall, full of ice, at a depth of 70 meters. Martel gives a cut and section of this glacière.

THE GLACIÈRE DU TROU DE GLAS. (E. A. Martel, *La Géographie*, 1900, vol. I., page 52.)—In the range of the Grande Chartreuse.

THE CHOURUN MARTIN. (E. A. Martel, *La Géographie*, 1900, vol. I., page 53.)—In the range of the Dévoluy, Hautes-Alpes; altitude 1,580 meters. An extremely deep pit, which on July 31st, 1899, was much blocked up with snow.

THE CHOURUN DE LA PARZA. (E. A. Martel, *La Géographie*, 1900, vol. I., page 54.)—In the range of the Dévoluy, Hautes-Alpes; altitude 1,725 meters. A fine pit, 25 meters in diameter, and 74 meters in depth. Filled with snow or rather névé, in which are deep holes.

THE GLACIÈRE DE L'HAUT-D'AVIERNOZ. Described in Part I., page 2. (C. Dunant, *Le Parmelan et ses Lapiaz*, page 26; Browne, *Ice Caves*, etc., page 157.)—Mons. Dunant calls this glacière l'Haut d'Aviernoz; Mr. Browne calls it the Glacière du Grand Anu. By a plumb line held from the edge of the larger pit, Browne found that the ice floor was about 35 meters from the surface, which would give a level for the ice floor closely identical to the one I found. In July, 1864, he recorded a temperature of +1.1°.

THE GLACIÈRE DE L'ENFER. (G. F. Browne, *Good Words*, November, 1866; T. G. Bonney, *The Alpine Regions*, 1868, pages 95, 96; C. Dunant, *Le Parmelan et ses Lapiaz*, page 25.)—On Mont Parmelan. A pit cave with a steep slope of broken rock leading to a rock portal in the face of a low cliff. This opens into a roughly circular hall about 22 meters in diameter and 3 meters to 4 meters in height. A chink between the rock and the ice permitted Mr. Browne to scramble down three or four meters to where a tunnel entered the ice mass. Throwing a log of wood down this tunnel, a crash was heard and then a splash of water, and then a strange gulping sound. "The tunnel obviously led to a subglacial reser-

voir and this was probably covered by a thin crust of ice; the log in falling had broken this and then disturbed the water below, which then commenced bubbling up and down through the hole, and making a gulping noise, just as it does sometimes when oscillating up and down in a pipe."

Mons. C. Dunant of the *Club Alpin Français* describes a visit to the Glacière de l'Enfer. He mentions also a legend of a witch from a neighboring village who would get the ice from these caves and bring it down in the shape of hail on the crops of the peasants who were inhospitable to her.

THE GLACIÈRE DE CHAPUIS. Described in Part I., page 5. (Browne, *Ice Caves*, etc., page 182, and *Good Words*, November, 1866.)—Mr. Browne calls it the Glacière de Chappet-Sur-Villaz. Mr. Browne and Professor T. G. Bonney found several flies in the Glacière de Chapuis. Three of them were specimens of *Stenophylax*, the largest being probably, but not certainly, *S. hieroglyphicus* of Stephens. Two smaller caddis flies were either *S. testaceus* of Pictet or some closely allied species. One other insect was an ichneumon of the genus *Paniscus*, of an unidentified species. It differed from all its congeners in the marking of the throat, resembling in this respect some species of *Ophion*. Mr. Browne thinks that the case flies may have been washed into the cave somehow or other in the larva form, and come to maturity on the ice where they had lodged. But this explanation will not

hold in the case of the ichneumon, which is a parasitic genus on larvæ of terrestrial insects.

THE GLACIÈRE DE LE BREZON. (Pictet, *Bibliothèque Universelle de Genève*, 1822, vol. XX., page 270, and Thury, *Bibliothèque Universelle de Genève*, 1861, vol. X., pages 139 and 152.)—It lies southeast of Bonneville near the foot of Mount Lechaud, at an altitude of 1276 meters. The cave is 9.7 meters long, about 8 meters wide and the greatest height is about 4 meters. The entrance is small and is at the base of a cliff, in some places of which cold air currents issue. The ice lies on the floor. Some of it is probably winter snow.

THE GLACIÈRE DE BRISONS.—Described in Part I., page 1.

THE GRAND CAVE DE MONTARQUIS. Described in Part I., page 70. (Thury, *Bibliothèque Universelle de Genève*, vol. X., pages 135–153.)—Professor Thury describes two visits to this cave. On the 16th of August, 1859, he found no ice stalactites or stalagmites. On the 19th of January, 1861, he did not find a single drop of water in the cave, but many stalactites and stalagmites of beautiful clear ice, one of which resembled porcelain more than any other substance. In August, Thury found an air current streaming into the cave at the rear, but this did not, however, disturb the air of the interior, for in one part it was in perfect equilibrium: along the line of the draughts the ice was more melted than elsewhere in the cave. In January, the

current was reversed and poured into the fissure, with the temperature varying between —1.5° and —2.5°. He observed the following temperatures at the Grand Cave :—

	TIME.	OUTSIDE.	INSIDE.
16th August, 1859		+ 8.6°	+ 2.5°
19th January, 1861	1.25 P. M.	+ 2.6°	— 4.°
" " "	2.12 "	+ 2.1°	— 4.°
" " "	3.50 "	— 1.1°	— 4.°

THE PETITE CAVE DE MONTARQUIS. Mentioned in Part I., page 71. (Thury, *Bibliothèque Universelle de Genève*, 1861, vol. X., page 150. Also quotes Morin.)—At the end of a crooked fissure 10 meters deep, a passage 6 meters long, leads into a cave 8 meters high and 5 meters in diameter. In August, 1828, Morin found an ice stalagmite of 5 meters in height in the middle of the cave.

CAVE CONTAINING ICE ON THE SOUTHERN SHORE OF LAKE GENEVA.—Reported; no information.

THE GLACIÈRE AND NEIGIÈRE D'ARC-SOUS-CICON. (Browne, *Ice Caves*, etc., page 118.)—These lie close together in the Jura about twenty kilometers from Pontarlier. The little glacière is formed by a number of fissures in the rock, disconnected slits in the surface opening into larger chambers where the ice lies. The neigière is a deep pit, with a collection of snow at the bottom, much sheltered by overhanging rocks and trees. A huge fallen rock covers a large part of the sloping bottom of the pit, which forms a small cave in the shape of a round soldier's tent, with walls of rock and floor of ice.

THE GLACIÈRE DE LA GENOLLIÈRE. Described in Part I., page 48. (Browne, *Ice Caves*, etc., page 1.)—Mr. Browne observed in 1864 a temperature of + 1.1°, and two days later of + 0.8°. He also found a number of flies running rapidly over the ice and stones. He was told in England, from the specimen he brought away, that it was the *Stenophylax hieroglyphicus* of Stephens or something very like that fly.

THE GLACIÈRE DE SAINT-GEORGES. Described in Part I., page 62. (Thury, *Bibliothèque Universelle de Genève*, 1861, vol. X.)—Professor Thury obtained the following temperatures at the Glacière de Saint-Georges:—

	OUTSIDE.	INSIDE.
9th January, 1858 . . .	7.36 P. M., —4.5°	7.16 P. M., —0.6°
" " " . . .		7.20 " —1.2°
" " " . . .		7.27 " —2.5°
" " " . . .		7.50 " —2.9°
Minimum of night . . .	—5.8°	—4.9°
10th January, 1858 . . .	10.53 A. M., —3.4°	10.12 A. M., —4.6°
" " " . . .	11.14 " —3.1°	10.30 " —4.5°
" " " . . .	11.45 " —2.2°	11.20 " —4.4°
" " " . . .	12.32 P. M., —2.4°	12.14 P. M., —4.4°
" " " . . .	1.12 " —0.9°	1.30 " —4.2°
" " " . . .	3.03 " —2.9°	2.30 " —4.1°
" " " . . .	3.56 " —3.5°	3.14 " —4.0°
" " " . . .	4.26 " —3.7°	4.00 " —3.8°
Minimum of night . . .	—7.6°	—6.8°
11th January, 1858 . . .		9.34 A. M., —5.6°
2d April, 1858	6.20 P. M., +0.7°	—0.2°
Minimum of night . . .	+1.1°	
3d April, 1858	10.00 A. M., +4.0°	9.00 A. M., —1.0°

Professor Thury's winter excursions caused him to accept as proved that part of the mountaineers' belief, which holds that there is no ice formed in caves in winter. One of the main grounds for his opinion was the series of observations he made in the Glacière de Saint-Georges. He found no ice forming there in winter and the natives said it did not because the cavern was not cold enough. So he placed large dishes filled with water in the cave and found that they froze solid during the night, which he had been assured was impossible. Thury also found violent movements of the air at Saint-Georges in January, 1858. A candle burned steadily for some time, but at 7.16 P. M. it began to flicker and soon inclined downwards through an angle of about 45°; and in the entrance, the flame assumed an almost horizontal position. At 8 P. M., the current of air nearly disappeared. Thury thought that this violent and temporary disturbance of equilibrium was due to the fact that as the heavier air outside tended to pass into the cave, the less cold air within tended to pass out; and the narrow entrance confining the struggle to a small area, the weaker current was able for a while to hold its own.

THE GLACIÈRE DU PRÉ DE SAINT-LIVRES. Described in Part I., page 65. (Browne, *Ice Caves*, page 40.)—Mr. Browne found, in 1864, a temperature of 0°.

THE PETITE GLACIÈRE DU PRÉ DE SAINT-LIVRES. (Browne, *Ice Caves*, page 46.)—This is near the last cave at a slightly higher altitude. There is first a small pit,

then a little cave, in which there is an ice slope. This passes under a low arch in the rock wall, and leads down into another small cave. Mr. Browne descended this ice stream, which was itself practically a fissure column and spread into the fan shape at the base. The lower cave was 22 meters long and 11 meters wide, and contained an ice floor and several fissure columns.

THE GLACIÈRE DE NAYE, ABOVE MONTREUX, SWITZERLAND. (E. A. Martel, *Les Abimes*, page 397; *Spelunca*, 1895, vol. I., pages 107, 108; *Mémoires de la Société de Spéléologie*, vol. III., pages 246-254.)—This is called a *glacier souterrain*. It was discovered in 1893 by Professor Dutoit. There are fifty-four caves known among the Rochers de Naye, and only this one contains ice. It is a long narrow cave with two entrances and widest towards the base, which opens over a precipice. The altitude is high, the upper entrance being at an altitude of 1820 meters, and the lower of 1750 meters. The place is both a passage cave and a windhole. The snow falls into the upper entrance, and slides down, becoming ice in the lower portion. There are other connecting passages and hollows where the cold air cannot get in, and there ice does not form. Mons. Martel thinks that the ice formed during the winter is preserved by the draughts—due to the difference in level of the two openings—causing an evaporation and chill sufficient for the purpose.

THE CREUX BOURQUIN. (E. A. Martel, *Les Abimes*, page 397.)—At Mauberget, near Grandson. This is a

rock gorge 25 meters deep. At the bottom, on the 9th of July, 1893, was a mass of ice 38 meters long and 8 meters wide.

THE GLACIÈRE DE MONTHÉZY. (Browne, *Ice Caves*, page 97.)—This lies to the west of Neufchâtel, between the Val de Travers and the Val de Brévine, on the path between the villages of Couvet and Le Brévine, at an altitude of 1100 meters. The cave is nearly oval in shape, with a length of 34 meters and a width of 29 meters. The roof is from 1 meter to 3 meters high. There are three pits, about 20 meters deep, on different sides of the cave. The descent is made through the largest pit. On the 6th of July, 1864, Mr. Browne found the floor of the cave covered with ice, and icicles and columns in some places; he also saw a clump of cowslips (*primula elatior*) overhanging the snow at the bottom of the pit through which he descended.

PERTIUS FREISS. (T. G. Bonney, *Nature*, vol. XI., page 327.)—It lies on the way to the Pic d'Arzinol, near Evolène, in the Val d'Hérens. A slip or subsidence of part of a cliff has opened two joints in the rock, in both of which fissures Professor Bonney found ice on July 23d.

THE SCHAFLOCH. Described in Part I., page 21. (Körber, *Jahrbuch des Schweizer Alpen Club*, 1885, vol. XX., pages 316, 343.)—Herr Körber gives some of the dimensions as follows: Entrance 14 meters wide and 4.70

meters high. Length of cave 206.8 meters: average width 20 meters and greatest width 23.5 meters. Height from 5 meters to 7 meters. Length of ice slope 29 meters and breadth 12.5 meters; for 16 meters the slope has an inclination of 32°. Körber made the following observations in the Schafloch:—

DATE.	OUTSIDE.	14 METERS FROM ENTRANCE.	100 METERS FROM ENTRANCE.	160 METERS FROM ENTRANCE.
21 September, 1884,	10.5°	5.6°	0.2°	0.2°
18 January, 1885, . .	2.7°	—1.0°	—1.3°	—

The Rev. G. F. Browne, in 1864, found a temperature of +0.5°.

THE EISLOCH OF UNTERFLUH. (Baltzer, *Jahrbuch des Schweizer Alpen Club*, 1892–93, pages 358–362.)—Twenty minutes from Unterfluh near Meiringen. A long narrow rock crack, some 30 meters deep and running some distance underground.

WINDHOLES AND MILKHOUSES OF SEELISBERG.—Described in Part I., page 45.

WINDHOLES ON THE SPITZFLUH. (Fugger, *Eishöhlen*, page 92.)—These are situated between Oltingen and Zeylingen, Canton Bâle: they generally contain ice till the end of July.

WINDHOLES ON THE BLUMMATT. (Fugger, *Eishöhlen*, page 93.)—On the northwestern slope of the Stanzerberg. Ice sometimes lies over in these windholes.

WINDHOLES NEAR BOZEN. (Fugger, *Eishöhlen*, page 97.)—On the Mendel ranges in Eppan, southwest of Bozen, among porphyry rocks. There are strong wind-streams. Ice is said to remain till late in the summer.

GROTTO ON MONTE TOFANA, DOLOMITES. (T. G. Bonney, *Nature*, vol. XI., page 328.)—This is probably a rudimentary glacière.

HOLES WITH ICE NEAR LIENZ. (Fugger, *Eishöhlen*, page 97.)—One hour and a half distant near Aineth, is a small cave containing ice, and further up the valley towards Huben, are several windholes.

EISHÖHLE AM BIRNHORN. (Fugger, *Eishöhlen*, page 131.)—Near Leogang in the Pinzgau. Altitude 2150 meters. There are two entrances, from which a slope 10 meters long, set at an angle of 25°, leads to an ice floor 12 meters long and 3 meters high. Then comes a small ice slope, and a little horizontal floor at the back. Explored by Fugger.

GLACIÈRES ON THE EISKOGEL. (Fugger, *Eishöhlen*, page 19.)—The Eiskogel is in the Tennengebirge, a mountain mass lying east of Pass Lueg. At an altitude of about 1900 meters, are two small caves, about 30 meters to 40 meters apart. They are some 25 meters in length and get smaller towards the bottom.

HOLES WITH ICE IN THE TENNENGEBIRGE, BETWEEN THE SCHALLWAND AND THE TAUERNKOGEL. (Fugger, *Eishöhlen*,

page 20.)—In this gorge are some small holes at an altitude of about 2000 meters, which are said to contain ice in summer.

THE SEEOFEN. (A. Posselt-Csorich, *Zeitschrift des Deutschen und Oesterreichischen Alpen Verein*, 1880, page 270.) On the Hean Krail in the Tennengebirge, at an altitude of about 1900 meters. The entrance faces southwest, and is 6 meters high and 4.5 meters wide. The cave is 25 meters long, and 8 meters wide. The floor of the cave is 13 meters below the entrance.

THE POSSELTHÖHLE. (A. Posselt-Csorich, *Zeitschrift des Deutschen und Osterreichischen Alpen Verein*, 1880, page 273.)—Named after its discoverer. It lies on the Hochkogel in the Tennengebirge, at an altitude of about 1900 meters. The entrance faces southwest, and is about 8 meters high and 8 meters wide. From the entrance the cave first rises, then sinks again below the level of the entrance, where the ice begins. The cave is about 20 meters wide. About 180 meters were explored, to a point where a perpendicular ice wall, 6 meters high, barred the way. About 125 meters from the entrance, there was an ice cone about 7 meters high.

THE GAMSLOCH OR DIEBSHÖHLE. (Fugger, *Eishöhlen*, page 14.)—It lies on the Breithorn of the Steinernes Meer, near the Riemannhauss, at an altitude of about 2180 meters. The entrance faces south. There is first a

small, then a larger chamber. The latter is some 40 meters long, by 5 meters or 6 meters wide. The ice is in the large chamber.

EISHÖHLE AM SEILERER. (Fugger, *Eishöhlen*, page 15.)—On the eastern side of the Seilerer arête on the Ewigen Schneeberg, west of Bischofshofen, at an altitude of about 2400 meters, is a small glacière cave.

CAVE IN THE HAGENGEBIRGE, WEST OF PASS LUEG. (Fugger, *Eishöhlen*, page 15.)—It lies about 2 kilometers east of Kalbersberg, at an altitude of about 2000 meters. A snow slope, with an ice floor at the bottom, leads into a long cave, about which little is known.

THE NIXLOCH. Described in Part I., page 57. (Fugger, *Eishöhlen*, page 98.)—Professor Fugger gathered some valuable data in connection with the Nixloch. In August, 1879, he found the air current entering downwards; on September 14th, 1879, there was no current either way. On Christmas day, 1878, on the contrary, the draughts were reversed, pouring out of the hole with a temperature of + 7.4°: the outside air then being —7.4°. At this time the known lower opening was in existence.

THE KOLOWRATSHÖHLE. Described in Part I., page 18. (Fugger, *Beobachtungen*, etc., page 7.)—This cavern has been more carefully studied than any other glacière cave. Some of its dimensions are given by Professor Fugger as follows: From the entrance to the ice floor, 26.6 meters;

surface covered by ice as measured on a plane, 2940 square meters; approximate cubical measure of entire cave, 92,000 cubic meters. The height of the entrance is 7 meters, with a width at the base of 2.7 meters, and at the top of 6.6 meters.

On the entrance slope occurred the only fatal accident I know of in glacières. In 1866, the Bavarian minister Freiherr von Lerchenfeld tried to descend; a wooden handrail which had been erected over the snow broke under his weight; von Lerchenfeld fell to the bottom of the cave and died a few days after from the injuries he received.

Of the Kolowratshöle, we have numerous thermometric observations by Professor Fugger, of which I select a few.

DATE.	OUTSIDE.	ENTRANCE.	INSIDE.	REAR.
21 May 1876	+6.5°	+0.7°	+0.03°	0° & +0.08°
18 June 1876	+5.1°	+1.6°	+0.23°	+0.4°
24 June 1876	+10.°	+1.6°	+0.4°	—
5 July 1876	—	—	+0.4°	—
22 July 1876	+11.3°	+1.5°	+0.4°	+0.2°
29 July 1876	+15.2°	+2.4°	+0.3°	+0.2°
22 Aug. 1876	+19.8°	+4.0°	+0.4°	+0.25°
20 Sept. 1876	+ 7.2°	+3.0°	+0.45°	+0.6°
22 Sept. 1876	—	—	+0.3°	—
16 Oct. 1876	+14.8°	+2.05°	+0.2°	+0.2°
22 Oct. 1876	+ 5.6°	+2.5°	+0.25°	+0.4°
26 Nov. 1876	+ 4.4°	+0.4°	—1.0°	—
6 Jan. 1877	+ 2.1°	+1.2°	—1.65°	—0.6°

THE SCHELLENBERGER EISGROTTE. (Fugger, *Beobachtungen in den Eishöhlen des Untersberges*, page 80.)—On the southeast slope of the Untersberg near Salzburg, at an

altitude of 1580 meters. The path leads past the Kienbergalp over the Mitterkaser and the Sandkaser. In front of the entrance is a sort of rock dam, 30 meters long and 5 meters or 6 meters higher than the entrance. Masses of snow fill the space between the two. The entrance is about 20 meters wide and from 2 meters to 3 meters high. A snow slope of 25 meters in length, set at an angle of 25°, leads to the ice floor. The cave is 54 meters long, from 13 meters to 22 meters broad and from 4 meters to 10 meters high. The cave has been repeatedly examined by Fugger, who has always found most snow and ice in the beginning of the hot weather, after which it gradually dwindles away.

Of the Schellenberger Eisgrotte, we have the following thermometric observations by Professor Fugger:—

DATE.	OUTSIDE.	ENTRANCE.	INSIDE.
29 June, 1877	+18°	—	+0.38°
24 " 1881	+21°	+2.3°	+0.24°
28 Aug., 1878	+14.6°	—	+0.2°
12 " 1879	+17.8°	—	+0.3°
4 Oct., 1876	+16.7°	+1.4°	+0.3°
9 " 1880	+ 3.6°	+3.5°	+0.3°
2 " 1887	+ 5.4°	—	+0.4°
9 " 1887	+ 8.2°	—	+0.4°
11 Nov., 1877	+ 7.4°	—	+0.2°

THE GROSSER EISKELLER OR KAISER KARLS HÖHLE. (Fugger, *Beobachtungen*, etc., page 58.)—On the Untersberg, between the Salzburger Hochthron and the Schweigmüller Alp. Altitude 1687 meters. A stony slope of 26 meters in length leads to an ice floor which is 26 meters long and 6 meters to 8 meters wide.

THE KLEINER EISKELLER. (Fugger, *Beobachtungen*, etc., page 73.)—Near the last. A small cave 8 meters long, 6 meters wide, 8 meters high.

THE WINDLÖCHER ON THE UNTERSBERG. (Fugger, *Beobachtungen*, etc., page 73.)—On the Klingersteig, at an altitude of 1300 meters. Four small caves of about 12 meters each in length and 8 meters in depth, and communicating at the bottom. There are strong draughts among them. In one of the caves is a small pit of great depth.

THE EISWINKEL ON THE UNTERSBERG. (Fugger, *Beobachtungen*, etc., page 77.)—Between the Klingeralp and the Vierkaser, at an altitude of 1600 meters. A small cave or rather rock shelter.

WINDHOLES ON THE UNTERSBERG. (Fugger, *Eishöhlen*, pages 103, 104.)—Windholes have been found by Fugger on the lower slopes of the Untersberg:

Near the Hochbruch at Fürstenbrunn.

In the débris of the Neubruch.

In the débris of the Veitlbruch.

HOTEL CELLAR AT WEISSENBACH ON THE ATTERSEE. (Fugger, *Eishöhlen*, page 20.)—There is a small cave here, at an altitude of 452 meters, which is utilized as a cellar, and which is said to contain ice in summer.

CAVE NEAR STEINBACH. (Fugger, *Eishöhlen*, page 20.)—A small cave containing ice on the northwest slopes of the Höllengebirge. Altitude about 700 meters.

THE KLIEBENSTEINHÖHLE OR KLIMMSTEINHÖHLE. (Fugger, *Eishöhlen*, page 20.)—On the north slope of the Höllengebirge, near the Aurachkar Alp, between Steinbach and the Langbath Lakes. Altitude about 1300 meters. Length about 40 meters, width 20 meters, height 15 meters.

THE WASSERLOCH. (Fugger, *Eishöhlen*, page 21.)—On the south slope of the Höllengebirge, near the Spitzalpe. Altitude about 1350 meters. At the bottom of a gorge is a snow heap and a small cave. The snow becomes ice in the cave.

CAVE ON THE ZINKENKOGL NEAR AUSSEE. (Fugger, *Eishöhlen*, page 21.)—Altitude about 1800 meters. A snow slope leads to an ice floor 18 meters long and 4 meters wide.

CAVE ON THE KASBERG. (Fugger, *Eishöhlen*, page 22.)—South of Grünau near Gmunden. Altitude about 1500 meters. Small cave 12 meters long, 4 meters wide.

THE WASSERAUFSCHLAG ON THE ROTHEN KOGEL. (Fugger, *Eishöhlen*, page 22.)—A tunnel near Aussee. The ice in it was formerly used.

THE GSCHLÖSSLKIRCHE. (Fugger, *Eishöhlen*, page 22.)—On the Dachstein range, facing the Lake of Gosau. A small cave, mostly filled with snow.

CAVE WITH ICE ON THE MITTERSTEIN. (Fugger, *Eishöhlen*, page 23.)—On the Dachstein, one hour and a quar-

ter from the Austria hut. Altitude about 1800 meters. Cave 5 meters to 6 meters wide, 30 meters long. In the rear a passage leads apparently to a windhole where there is a strong draught.

WINDHOLES IN THE OBERSULZBACH VALLEY IN THE PINZGAU. (Fugger, *Eishöhlen*, page 105.)—Fugger found ice among these on the 1st of August, 1886.

ICE IN AN ABANDONED NICKEL MINE ON THE ZINKWAND, IN THE SCHLADMING VALLEY. (Fugger, *Eishöhlen*, page 105.)

WINDHOLES ON THE ROTHEN KOGEL NEAR AUSSEE. (Fugger, *Eishöhlen*, page 106.)—These were found to contain ice on the 2d of September, 1848.

CAVE ON THE LANGTHALKOGEL. (Fugger, *Eishöhlen*, page 23.)—On the Dachstein plateau between Hallstatt and Gosau. A small cave which contains ice.

EISLUNGHÖHLE. (Fugger, *Eishöhlen*, page 24.)—A small cave between the Hochkasten and Ostrowiz in the Priel range.

THE GELDLOCH OR SEELÜCKEN ON THE OETSCHER. (Schmidl, *Die Höhlen des Ötscher* and *Die Oesterreichischen Höhlen;* Cranmer and Sieger, *Globus*, 1899, pages 313–318, and 333–335.)—The second known notice of a

glacière cave is the account of a visit to the Oetscher Caves in 1591. After lying in manuscript for two and a half centuries, it was published by Dr. A. Schmidl in 1857, in *Die Höhlen des Ötscher*, pages 21–36. According to the account, which is naive, but evidently truthful, Kaiser Rudolf II. ordered Reichard Strein, owner of the Herrschaff Friedeck, to investigate the Otscher and especially its caves. He did so, with the title of *Kaiserlicher Commissarius*, and accompanied by the *Bannerherr* Christoph Schallenberger, Hans Gasser, and eleven porters. On September the 16th, 1591, they visited the Seelücken, where they found a lake in the front of the cave, and where the party had great difficulties in climbing round on to the ice.

The Seelücken on the Oetscher is situated at an altitude of 1470 meters. It opens nearly due south. The ice floor is about 20 meters below the entrance and is about 38 meters long and 24 meters wide; at the rear, it rises for some 15 meters as an ice wall at an angle of about 60°, and then forms a second ice floor about 45 meters long by 19 meters wide. The front part of the ice is sometimes, about July, covered with water. The cave continues further back, in two branches, and Professors Cranmer and Sieger consider that it is a large windhole, in which draughts are infrequent, on account of its length and because the openings are near the same level. There are also several up and down curves and in these cold air remains and acts something like a cork in stopping draughts.

On the 13th of September there were no draughts, and the temperatures between 11 A. M. and 12 M. were:—

Outside air	+7.1°
Inside near entrance	+1.5°
A little further in	+1.1°
At the lowest point near ice	+0.8°

On the 31st of October, 1897, there was a draught, which followed the curves of the cavern, and which flowed out at the southern end. The temperatures were:—

Outside air	+3.7°
Inside near entrance	+1.3°
At the lowest point near ice	+0.8°
On the second, higher ice floor	+1.0°
In the main passage behind ice	+1.4°

CAVE ON THE KÜHFOTZEN NEAR WARSHENECK. (Fugger, *Eishöhlen*, page 25.)—A small cave containing ice.

EISKELLER ON THE RAX. (Fugger, *Eishöhlen*, page 25; Cranmer, *Eishöhlen*, etc., page 61.)—Altitude about 1660 meters. A doline with a small cave at the bottom, in which melting snow was found on the 19th of September, 1896.

THE TABLERLOCH. (Cranmer, *Eishöhlen*, etc., pages 19–60.)—On the Dürren-Wand in the mountains south of Vienna, 2 hours distant from Miesenbach R. R. station. Altitude about 1000 meters. Entrance 7 meters wide, 3.5 meters high. Slope 30° from entrance. Lowest point 22 meters below entrance. Extreme length of cave 50

meters, width 23 meters, height 15 meters. Professor Cranmer found fresh ice beginning to form on the 12th of November, 1893; on the 1st of December, 1894; and on the 20th of October, 1895. He found it melting away on the 3d of June, 1894; on the 1st of June, 1895; and on the 31st of May, 1896. The rates at which the ice formed or melted, however, were not always the same in different parts of the cave. The greatest amount of ice observed seems to have been in March and April. In the summer months no perceptible movements of air seem to have been noticed. This was also sometimes the case in the winter months, during which, however, movements of air were at other times plainly perceptible.

THE GIPSLOCH. (Cranmer, *Eishöhlen*, etc., page 60.)—A small cave on the Hohen-Wand near Wiener-Neustadt. It is rather a cold cave than a glacière.

THE WINDLOCH. (Cranmer, *Eishöhlen*, etc., page 61.)—On the Hohen-Wand near Wiener Neustadt. Small cave. Snow found in it on June the 2d, 1895.

EISLOCH IN THE BRANDSTEIN ON THE HOCHSCHWAB. (Cranmer, *Eishöhlen*, etc., page 64.)—Altitude about 1600 meters. A moderately large cave. On the 21st of August, 1895, there was an ice floor 10 meters long and 5 meters broad. Temperature in rear of cave, —0.2°.

CAVES ON THE BEILSTEIN. (Krauss, *Höhlenkunde*, 1894, pages 207–219; Cranmer, *Eishöhlen*, etc., page

63.)—These lie about 4 hours on foot from Gams in Steiermark, at an altitude of 1260 meters, in a place where the mountain is much broken up by fissures and snow basins. The large cave has two openings, from which steep snow slopes descend. The cave is 60 meters long, 15 meters to 18 meters broad, and about 7 meters high. Clefts in the rock in two places lead to two lower, small ice chambers. In the neighborhood of the large cave are two small ones. Prof. Cranmer found fresh ice in the Beilsteinhöhle on the 20th of August, 1895. Two days before, fresh snow had fallen on the neighboring mountain peaks.

EISHÖHLE ON THE BRANDSTEIN. (Cranmer, *Eishöhlen*, etc., page 62.)—A small cleft cave near the Langriedleralm near Gams in Steiermark. On the 20th of August, 1895, it contained some ice.

THE FRAUENMAUERHÖHLE.—Described in Part I., page 37.

THE BÄRENLOCH NEAR EISENERZ. (Fugger, *Eishöhlen*, page 28.)—In the neighborhood of the Frauenmauerhöhle. Altitude 1600 meters. A steep snow slope leads to an ice floor 13 meters long.

THE KATERLOCH. (Fugger, *Eishöhlen*, page 29.)—On the Göserwand near Dürnthal, Glemeinde Gschaid in Steiermark. A large cave, some 190 meters long and 80

meters wide. A thin ice crust has been found on parts of the walls in the rear.

CAVES IN THE STEIN ALPS. (Fugger, *Eishöhlen*, page 29.)—The plateau of Velica Planina lies, at an altitude of 1600 meters, 9 kilometers north of Stein in the Duchy of Krain. There are three caves containing ice on the plateau. The first is a big one and is called V. Kofcih. The second is called Mala Veternica. The third and biggest is called Velika Veternica; its length is about 100 meters and its breadth 30 meters.

GLACIÈRE CAVES ON THE NANOS MOUNTAIN. (Fugger, *Eishöhlen*, page 34.)—In the southwestern Krain, 5 kilometers from Präwald. There are four caves containing ice reported on the Nanos mountain. Two of them are big. The altitude of one of these is 1300 meters, of the other 1350 meters.

BRLOWA JAMA. (Fugger, *Eishöhlen*, page 36.)—Seven kilometers from Adelsberg. Small glacière cave.

KOSOVA JAMA. (Fugger, *Eishöhlen*, page 38.)—Near Divacca. Forty meters long, 20 meters broad.

GLACIÈRE NEAR ADELSBERG. (Fugger, *Eishöhlen*, page 36.)—Small cave. One hour from Adelsberg.

KACNA JAMA. (J. Marinitsch, *La Kacna Jama*, *Mémoires de la Société de Speléologie*, vol. I., page 83.)—A great pit near the railroad station of Divacca. Herr Mar-

initsch observed the following temperatures on January 2d, 1896:—

At Divacca	— 2° C.
In the Kacna Jama at 40 meters . . .	— 1.1° C.
" " " " " 100 meters . .	+ 1.2° C.
" " " " " 210 meters . .	+ 2.1° C.

SANCT CANZIAN, KARST. (E. A. Martel, *Les Abimes*, page 564, note.)—During the winter of 1889–1890, Herr Marinitsch found stalactites of ice as far as the seventeenth cascade of the Recca; 1000 meters from the third entrance of the river. The temperature of the Recca was then at 0°; during the summer, the temperature of the water rises to 27° (?).

THE GROSSES EISLOCH OF PARADANA. (Fugger, *Eishöhlen*, page 36.)—On the high plateau of the forest of Tarnowa, east of Görz. A large pit cave, 30 meters to 40 meters deep. Professor Fugger says of it: "The flora in the basin-like depression has the character of high mountain vegetation, with every step it resembles more this flora as it exists in the neighborhood of glaciers, until finally in the deepest point of the basin all vegetation stops."

THE KLEINES EISLOCH OF PARADANA. (Fugger, *Eishöhlen*, page 37.)—A small pit glacière, 500 meters distant from the Grosses Eisloch of Paradana.

SUCHY BREZEN. (Fugger, *Eishöhlen*, page 37.)—A small pit glacière, situated about midway between the Grosses and Kleines Eisloch of Paradana.

Prevalo Cave. (Fugger, *Eishöhlen*, page 37.)—In the Buchenhochwald, south of Karnica. Small glacière.

Cave of Dol. (Fugger, *Eishöhlen*, page 38.)—On a mountain near Haidenschaft. Small glacière.

Glacière near Matena in Bezirke Radmansdorf. (Petruzzi in Haidinger's *Berichte*, etc., vol. VII., page 68.)—On a wooded height. The ice commences to melt in the early summer.

Glacière on the Schutzengelberge near the Golac. (Petruzzi in Haidinger's *Berichte*, etc., vol. VII., page 64.)—A small glacière.

Glacière Cave near Lazhna-gora or Latzenberg. (Valvasor, *Die Ehre des Herzogthumes Crain*, vol. I., pages 242, 243; Hacquet, *Oryctographia Carniolica*, 1778, III., page 159.)—In the neighborhood of Vishnagora in the Krain. The entrance is under a church. It is a large cave, 40 meters long and 20 meters high, where the ice all melts by the end of the summer. Valvasor gives the following account of this cave in 1689, which seems the first printed notice of a glacière in German:—

"Near to Lazchenberg up by the church of St. Nicholas, where a *Thabor* stands, one finds a big hole, which sinks into the stony rocks. Through this one descends deep with torches: there opens then underneath as big a cavity as the biggest church could be, and the same is extremely high, in the form of a cupola. One sees there

different teeth, formed and hardened from the water turned to stone. Further down one arrives to a deep gully: into which, however, I have not been. On the other side one must again ascend, and then one comes again to a cupola: in which cupola ice stands up like an organ from the earth.

"There also one sees icicles of pure ice of different sizes and heights, of which many are one or two *klafters* high and as thick as a man; but many only two or three spans high or higher, and as thick as an arm, and some also thinner. This ice is formed from the drops of falling water; and indeed in summer; for in winter there is no ice therein. Over such ice one must then ascend, as there are then said to be separate holes and grottoes. But no one has been any further."

GLACIÈRE ON THE DINI VERH. (Petruzzi in Haidinger's *Berichte*, etc., vol. VII., page 67.)—Near Tomischle in the Krain. Small glacière.

EISKELLER NEAR ROSSECK. (Petruzzi in Haidinger's *Berichte*, etc., vol. VII., page 64.)—On the Pograca Mountain in the Krain, northeast of the Hornwald, near the Meierhof Rosseck. Small glacière cave.

GORGE NEAR ROSSECK. (Valvasor, *Die Ehre des Herzogthumes Crain*, vol. I., page 243 and page 517; Petruzzi in *Haidinger's Berichte*, etc., vol. VII., page 64.)—Behind the ruined castle of Rosseck, on the Pograca Mountain in the Krain, is a gorge, at whose bottom are four little holes containing ice most of the year.

Valvasor wrote of this cave in 1689: "Near Rosseck immediately back of the castle there opens a mighty cavern entirely in stony rock, and yawns in the shape of a cauldron down into the earth. Above as wide as a good rifle shot, but below quite narrow. And there underneath there are many holes where the ice remains through the whole summer. From such ice have Duke Frederick Graf and Duke von Gallenberg daily made use in summer to cool their wine. Six years ago I descended there in the month of August, and found ice enough in all the holes."

In the same volume Freiherr Valvasor elaborates his remarks about this cave and that at Latzenberg, repeating in the main the observations in the paragraph just given. He says: "There hang also long icicles which are quite pleasant to look at. * * * This ice breaks all too easily and quickly. * * * Contrarywise, however, this ice lasts much longer in the sun and the heat than other ice. * * * Some might think it would eventually turn into stone: this, however, does not happen: for it remains only in summer and disappears in winter: as I can say for certain, as I have been in myself in the winter as well as in the summer time. * * * For as in the summer the floor is quite covered with ice: it makes walking so dangerous and bad that one cannot take a step without climbing irons; but in the winter time one goes safely and well. * * *"

Freiherr Valvasor was evidently an accurate observer, and, if for his word "winter" we substitute "autumn," his account will be much more nearly correct than might have been expected two centuries ago.

THE KUNTSCHNER EISHÖHLE. (Petruzzi in Haidinger's *Berichte*, etc., vol. VII., pages 65, 66.)—This is known also as the Töplitzer, Unterwarmberger or Ainödter Grotto. It lies 2 kilometers from Kuntschen, and 12 kilometers from Töplitz near Neustädtel, in the Krain. Altitude about 630 meters. Petruzzi says: "Of all so far noticed ice grottoes it is the most wonderful and splendid." In August and September, 1849, the temperatures near the ice were about two degrees above freezing. On the 16th of August, there were many long ice stalagmites and stalactites; on the 29th of September they had diminished materially. Petruzzi says also: "One leaves the abundant vegetation of the Alpine summer flora, and through bushes and dwarf underbrush, through bare and half moss covered rocks and débris, through rotten and twisted tree stems, one comes to the hall of eternal winter, where the microscopic mosses of the north surround the thousand year old stalactites, hanging from the dripping vault, with an always passing, always freshly forming, tender sulphur colored down." Dr. Schwalbe has also examined this cave.

THE FRIEDRICHSTEINER OR GOTTSCHEER EISHÖHLE.—Described in Part I., page 51.

THE HANDLER EISLOCH.—7 kilometers south of Gottschee and about twenty minutes from the village of Handlern, near Rieg. Altitude 596 meters. Small cave. Professor Hans Satter of Gottschee told me he doubted whether ice ever formed there now.

THE SUCHENREUTHER EISLOCH.—Described in Part I., page 55.

LEDENICA NA VELIKI GORI. (Petruzzi in Haidinger's *Berichte*, etc., vol. VII., page 67.)—In the Krain, 11 kilometers from Reifnitz, on the Balastena Mountain. Altitude 1253 meters. Much ice was found there on the 10th of July, 1834.

MRZLA JAMA. (Fugger, *Eishöhlen*, page 34.)—On the Innerkrainer Schneeberg, 13 kilometers from Laas.

GLACIÈRE CAVES ON THE KAPELLA. Fugger, *Eishöhlen*, page 39.)—On a pass in the neighborhood of Piacenza. Altitude 800 meters.

GLACIÈRE CAVE IN WEST BOSNIA. (Fugger, *Eishöhlen*. page 39.)—West of Kljuc, county Petrovac, district Smoljama, near village Trvanj. Called Trvanj, also Ledenica, Altitude about 1000 meters, length 170 meters, breadth from 4 meters to 30 meters.

RTANJ, SERVIA. (A. Boué, *La Turquie d'Europe*, 1840, vol. I., page 132; Dr. A. Cvijic, *Spelunca*, vol. II., 1896, pages 72–74.)—This glacière is on the south side of Siljak, near the village Muzinac. A passage 60 meters long leads to a hall about 10 meters in height. Dr. Boué found snow here in August, the thermometer standing below freezing point. The people in the neighborhood told Dr. Boué

that the snow is formed in June and disappears in September and that it is sometimes carried to Nisch. He also heard of similar cavities on the Bannat Mountain. Dr. Cvijic observed in the hall a temperature of + 0.4° C.

LEDENA PEC, SERVIA. (Dr. A. Cvijic, *Spelunca*, vol. II., 1896, pages 68, 69.)—On the Ledini Verh or Glacial Peak, at an altitude of 800 meters; distant one hour and a half from the village of Souvold. Length of passage 108 meters; at entrance about 6 meters, at end about 15 meters in height. On the 10th of May, 1893, there was plenty of ice and snow. Temperature of outside air + 19° C.; inside air at rear + 0.5° C. Probably permanent glacière.

DOBRA LEDENICA, SERVIA. (Dr. A. Cvijic, *Spelunca*, vol. II., 1896, page 70.)—West of Ledeno Brdo. Probably periodic glacière. On July 25th, 1890, the temperature of the outside air was + 26° C.; of the inside air + 3.5° C. *Ledenica* is the name for a glacière in Servia.

LEDENICA IN THE MALA BREZOVICA, SERVIA. (Dr. A. Cvijic, *Spelunca*, vol. II., 1896, page 70.)—Length 43 meters. A large, permanent glacière. On July 28th, 1890, the outside air was + 23°: inside air + 2°.

LEDENICA TREME IN THE SOUVA PLANINA, SERVIA. (Cvijic, Dr. A., *Spelunca*, vol. II., 1896, page 71.)—Altitude 1600 meters to 1700 meters. A rather large, probably permanent glacière. Plenty of ice in it on April 21st, 1894.

ZLA LEDENICA, SERVIA. (Dr. A. Cvijic, *Spelunca*, vol. II., 1896, page 72.)—On the Kucaj. A permanent glacière, 7 meters or 8 meters deep. On July 25th, 1890, outside air + 25°; inside air at snow + 6°.

GLACIÈRE ON THE DEVICA, SERVIA. (Dr. A. Cvijic, *Spelunca*, vol. II., 1896, page 74.)—Under the peak Lazurevica. Altitude 1000 meters. A narrow passage leads to a hall 17 meters long by 12 meters wide and 20 meters high. On June 30th, 1893, there was plenty of snow in the passage and ice in the hall.

GLACIÈRE VLASKA PECURA, SERVIA. (Dr. A. Cvijic, *Spelunca*, vol. II., 1896, page 74.)—On the Devica, under the Golemi Vech. A small periodic glacière.

GLACIÈRE IN THE ZDREBICA, SERVIA. (Dr. A. Cvijic, *Spelunca*, vol. II., 1896, page 74.)—On the southeast side of the Souva Planina, near the village Veliki Krtchimir. A small periodic glacière. On April 20th, 1874, plenty of snow and ice.

GLACIÈRE STOYKOVA, SERVIA. (Dr. A. Cvijic, *Spelunca*, vol. II., 1896, pages 75, 76.)—On the Kucaj. A large pit cave with a total depth of 23 meters. Probably a permanent glacière. On July 21st, 1890, plenty of ice and snow. Outside air + 21°; inside air in hall + 0.5°.

GLACIÈRE ON THE TOPIZNICA MOUNTAIN, SERVIA. (Dr. A. Cvijic, *Spelunca*, vol. II., 1896, page 76.)—Altitude

1100 meters. A large pit cave with an extreme depth of 27 meters. In August, 1893, there was plenty of snow and ice, and the inside temperature was + 1°.

Glacière Cave near Borszék. (Bielz, *Siebenbürgen*, 1885, page 334.)—About an hour distant from the baths, in broken limestone. It seems to be a rock fissure, at the end of which ice is found till towards the middle of July.

Glacière Cave near Sonkolyos in the Korös Valley. (Fugger, *Eishöhlen*, page 51.)—Small cave.

Glacière near Zapodia. (Fugger, *Eishöhlen*, page 50.)—Near Petrosc in the Bihar Mountains. Altitude 1140 meters; length 20 meters, width 7 meters.

Pescerca la Jesere. (Fugger, *Eishöhlen*, page 50.)—Between Vervul la Belegiana and the Batrina in the Bihar Mountains. Small freezing cave.

Glacière Cave near Verespatak, in Transylvania. (Bielz, *Siebenbürgen*, page 52.)—Small cave.

Gietariu near Funacza. (Fugger, *Eishöhlen*, page 50.)—In the Bihar Mountains. Small glacière cave.

Cave of Skerizora. (Karl F. Peters, *Sitzungsbericht der K. K. Akademie der Wissenchaften*, Wien, vol. XLIII., 1861, page 437; Bielz, *Siebenbürgen*, 1885, page 37.)—This is one of the greatest glacière caves known. It

lies in the Bihar Mountains, three hours from the village of Ober-Girda, which can be reached from Gyula Fehérvar, via Topánfalva. It is a pit cave, in limestone, at an altitude of 1127 meters. The pit is about 57 meters broad, and 45 meters deep, with exceedingly steep walls. The entrance is in the northeast wall and is about 10 meters high. This leads into a nearly circular hall 47 meters in diameter and about 20 meters high. The floor is ice. In the southeast corner is a hole over 75 meters deep. In the northwest wall is an opening 14 meters wide, which forms the beginning of a sort of gallery 54 meters long and which at its further end is 24 meters wide and 8 meters high. This is also covered with a flooring of ice, which in some places can only be descended by step cutting. This passage is also richly adorned with ice stalactites and stalagmites. At its end is another also nearly circular hall, 21 meters in diameter and about 22 meters high. This is called the '*Beszerika*' or church. In one place there is a magnificent collection of ice stalagmites called the "Altar." Peters found in dirt on the sides of the cave remains of bats not very different from those now living in the vicinity. He thinks the bats may have come there before the cave became a glacière; or else that they may even now sometimes get into the first hall and there perish from cold. This makes it uncertain, therefore, whether the remains can be considered as of the past or the present.

EISHÖHLE BEI ROTH.—Described in Part I., page 35.

MINES ON THE EISENBERG. (Fugger, *Eishöhlen*, page 59.)—These lie near Blankenburg in the Thüringer Wald and have been known to contain ice.

THE ZIEGENLOCH OR GROSSES KALTE LOCH, AND THE KLEINES KALTE LOCH. (Behrens, *Hercynia Curiosa*, pages 68, 70.)—These lie near Questenberg in the Southern Harz Mountains, at an altitude of about 300 meters. The Grosses Loch is described as a sort of small pit some 8 meters deep, in one side of which opens a small fissure some 10 meters long. Ice has been found in this in April; Schwalbe found none there in July. The Kleines Loch was another small cold cave near the Ziegenloch, but it has been filled up. Behrens says that the dampness at the cave at Questenberg is precipitated as snow.

HOLES WITH ICE NEAR SANCT BLASIEN. (Fugger, *Eishöhlen*, page 109.)—In the Black Forest, among boulders at an altitude of 820 meters.

HOLES WITH ICE NEAR HOCHENSCHWAND. (Fugger, *Eishöhlen*, page 109.)—In the Black Forest, among boulders at an altitude of 820 meters.

EISSTOLLEN AND EISKELLER AT THE DORNBURG. Described in Part I., page 59. (Poggendorff's *Annalen der Physik und Chemie*, *Ergänzungsband*, 1842, pages 517–519.)—Ice appears to have been discovered at the Dornburg in June, 1839. It was found from a depth of 60 centimeters down to 8 meters. The width of the ice-bearing

talus was from 12 meters to 15 meters; and it is said that it becomes wider in winter and narrower in summer.

BESCHERTGLUCK MINE, FREIBERG DISTRICT. (Prestwich, *Collected papers*, etc., page 206.)—Mr. Prestwich quotes Daubuisson as having seen the shaft of the mine lined with ice to a depth of 80 toises (144 meters?).

ICE IN THE ZINC MINES ON THE SAUBERG. (Reich, *Beobachtungen über die Temperatur des Gesteines*, 1834, pages 175 and 205.)—These are near Ehrenfriedersdorf in Saxony and formerly contained ice in winter. They are reported now to be destroyed.

THE GARISCHE STOLLEN. (Lohman, *Das Höhleneis*, etc., page 3.)—Near Ehrenfriedersdorf in the Freiwald. Lohman found much ice in this in January, less in March, and scarcely any in May.

THE RITTERHÖHLE. (Lohman, *Das Höhleneis*, page 5.)—Near Ehrenfriedersdorf in the Freiwald. Small ice deposit. The rock is granite.

THE STULPNERHÖHLE. (Lohman, *Das Höhleneis*, page 6.)—Near the Ritterhöhle. Small ice deposit in granite rock.

EISLOCH AND EISHÖHLE NEAR GEYER IN SAXONY. (Lohman, *Das Höhleneis*, page 7.)—These are in a place called die Binge. Both are small.

THE ALTE THIELE. (Lohman, *Das Höhleneis*, page 8.)—Near Buchholz in Saxony. Small ice deposit.

MINE PITS IN THE SAXON ERZGEBIRGE. (Reich, *Beobachtungen über die Temperatur des Gesteines*, 1834.)—Extremely low temperatures have been found in several of these pits:—

In the Churprinz Friedrich August Erbstollen near Freiberg.

In the Heinrichs-Sohle in the Stockwerk near Altenberg.

In the Henneberg Stollen, on the Ingelbach, near Johanngeorgenstadt.

In the Weiss-Adler-Stollen, on the left declivity of the valley of the Schwarzwasser, above the Antonshütte.

HOLES HOLDING ICE ON THE SAALBERG. (*Annalen der Physik und Chemie*, 1850, LXXXI., page 579.)—These lie between Saalberg and the Burgk. Ice is found here on the surface from June to the middle of August. From the observations of Professor Hartenstein, Fugger deduces that this place must be the lower end of one or more windholes.

MILLSTONE QUARRY OF NIEDERMENDIG. (M. A. Pictet, *Mémoires de la Société d'Histoire Naturelle de Genève*, 1821, vol. I., page 151.)—On the Niederrhein. There are many connecting pits and galleries here, in which ice has been found in the hottest days of summer as well as in March. The abandoned shafts are utilized as beer cellars.

EISGRUBE ON THE UMPFEN. (Voigt, *Mineralogische Reisen durch das Herzogthum Weimar*, 1785, vol. II., page 123.)—In the Rhöngebirge, twenty minutes from Kaltennordheim, are some irregular masses of columnar basalt, at an altitude of about 500 meters, among which abundant ice has been found up to late in the summer.

CAVE NEAR MUGGENDORF, FRANCONIA.—The landlord of the Kurhaus Hotel at Muggendorf, told me that there was a small cave in the vicinity where there was ice in the winter and spring, but that it all melted away before August.

CAVE ON THE DÜRRBERG. (Fugger, *Eishöhlen*, page 59.)—Near Zwickau in Bohemia. Small cave which sometimes contains ice.

THE SCHNEEBINGE. (Lohman, *Das Höhleneis*, page 11.)—Near Platten in Bohemia. A small ice deposit in an old mine.

ICE AMONG BASALTIC ROCKS ON THE PLESCHIWITZ. (Pleischl, in Poggendorff's *Annalen der Physik und Chemie*, vol. LIV., 1841, pages 292–299.)—Above Kameik near Leitmeritz in Bohemia. Professor Pleischl, in May, 1834, found ice under the rocks a little distance from the surface. The surface of the rocks was then warm. On the 21st of January, 1838, Professor Pleischl found snow on

the outside of the rocks, but no ice underneath. He was assured by the people of the district that the hotter the summer, the more ice is found.

GLACIÈRE ON THE ZINKENSTEIN. (Pleischl, in Poggendorff's *Annalen der Physik und Chemie*, vol. LIV., 1841, page 299).—The Zinkenstein is one of the highest points of the Vierzehnberge, in the Leitmeritz Kreis. There is a deep cleft in basalt, where ice has been found in summer.

EISLÖCHER ON THE STEINBERG. (Pleischl, in Poggendorff's *Annalen der Physik und Chemie*, vol. LIV., 1841, page 299.)—In the Herrschaft Konoged. Small basalt talus where ice is found in the hottest weather.

WINDHOLES IN BOHEMIA. (Fugger, *Eishöhlen*, page 109.)—In the neighborhood of Leitmeritz. These are in basaltic rock. Ice sometimes forms at the lower extremity. The most notable are—

On the Steinberg near Mertendorf on the Triebschbach;
On the Kelchberg near Triebsch;
On the Kreuzberg near Leitmeritz;
On the Rodersberg near Schlackenwerth;
In the Grossen Loch near Tschersink.

ICE IN A PIT NEAR NEUSOHL. (Fugger, *Eishöhlen*, page 109.)

THE FRAINER EISLEITHEN. Described in Part I., page 33. (Fugger, *Eishöhlen*, page 163.) Professor Fugger

quotes the following observations by Forester Wachtl at Frain:—

	1861.	1862.
January	— 7° to —2°	— 5°
February . . .	— 2° to 0°	— 5° to — 2°
March	0° to + 1°	— 1° to 0°
April	+ 1° to + 2°	0°
May	+ 2°	+ 2° to + 5°
June	+ 2° to + 3°	+ 3° to + 6°
July	+ 3°	+ 3° to + 5°
August	+ 3° to + 7°	+ 5°
September . . .	+ 7° to + 6°	+ 3° to + 6°
October	+ 6°	+ 5°
November	—	+ 5°
December . . .	— 1° to — 3°	0° to — 2°

Démenyfálva Jegbarlang. Described in Part I., page 24.

Dóbsina Jegbarlang. Described in Part I., page 13. (Pelech; *The Valley of Stracena and the Dobschau Ice Cavern*; Schwalbe, *Uber Eishöhlen und Eislöcher*, page 31.)—Pelech gives the following measurements: The Grosser Saal is 120 meters long, 35 meters to 60 meters wide, and 10 meters to 11 meters high, with a surface area of 4644 square meters. The ice mass is estimated as 125,000 cubic meters in volume. The length of the Korridor is 200 meters; the left wing being 80 meters, and the right wing 120 meters long. The cave was first entered on July 15th, 1870, by Herr Eugene Ruffiny, of Dóbsina, and some friends. He had happened to fire a gun in front of it, and hearing a continuous muffled rolling echo within, determined to explore it.

Dr. Schwalbe quotes the following series of observations in Dóbsina during the year 1881:

	ENTRANCE.	GROSSER SAAL	DEEPEST POINT OF KORRIDOR.	FROM KORRIDOR TO KLEINEN SAAL.
January . . .	—2.2°	—4.2°	—2.2°	—0.6°
February . . .	—1.2°	—3.4°	—1.9°	—0.3°
March	—1.4°	—2.1°	—0.9°	—0.2°
April	—0.25°	—1.25°	—0.7°	+0.3°
May	+0.7°	+0.9°	—0.5°	+0.5°
June	+1.0°	+1.5°	—0.5°	+0.5°
July	+1.8°	+2.1°	+0.2°	+1.1°
August	+3.4°	+3.8°	+0.24°	+0.8°
September .	+2.0°	+2.3°	—0.3°	—0.15'
October . . .	—0.2°	+0.2°	—0.5°	—0.2°
November . .	—1.3°	—1.9°	—0.6°	—0.3°
December . .	—2.2°	—3.2°	—0.65°	—1.75'
Year	+0 04	—0.44°	—0.69°	—0.02°

The Philadelphia *Evening Bulletin*, March, 1st, 1899, printed the following note about Dóbsina: "In this cave, some sixteen years ago, a couple named Kolcsey elected to pass the week immediately following their marriage. They took with them a plentiful supply of rugs, blankets and warm clothing, but notwithstanding all precautions, their experience was not of a sufficiently pleasant nature to tempt imitators."

LEDNICA OF SZILIZE. (M. Bel, *Philosophical Transactions*, London, 1739, vol. XLI., page 41 *et seq.;* Townson, *Travels in Hungary*, 1797; Terlanday, *Petermann's Mittheilungen*, 1893, page 283.)—It lies 1.5 kilometers from the village of Szilize, near Rosenau, in Gomör County, in the

Carpathians, at an altitude of 460 meters. A pit about 35 meters deep, 75 meters long, and 48 meters wide opens in the ground, and at the southern end, in the perpendicular wall, is the cave. The entrance is 22 meters wide, 15 meters high, and faces north. A slope 4 meters long sinks with an angle of 35° to the floor of the cave, which is nearly circular in form, with a diameter of about 10 meters. On the east side of the cave there seems to be a hole in the ice some 10 meters deep.

In 1739, there was published in London a curious letter in Latin from Matthias Bel, a Hungarian *savant*, about the cavern of Szilize. He says: "The nature of the cave has this of remarkable, that, when outside the winter freezes strongest, inside the air is balmy: but it is cold, even icy, when the sun shines warmest. As soon as the snow melts and spring begins, the inner roof of the cave, where the midday sun strikes the outside, begins to sweat clear water, which drops down here and there; through the power of the inner cold it turns to transparent ice and forms icicles, which in thickness equal large barrels and take wonderful shapes. What as water drops from the icicles to the sandy floor, freezes up, even quicker, than one would think.

"The icy nature of the cave lasts through the whole summer, and what is most remarkable, it increases with the increasing heat of the sun. In the beginning of the spring the soft winter's warmth begins to give way soon thereafter, and when spring is more advanced, the cold sets in, and in such a manner, that the warmer does the (outside)

air grow, the more does the cave cool off. And when the summer has begun and the dog days glow, everything within goes into icy winter. Then do the drops of water pouring from the roof of the cave change into ice, and with such rapidity that where to-day delicate icicles are visible, to-morrow masses and lumps, which fall to the ground, appear. Here and there, where the water drips down the walls of the cave, one sees wonderful incrustations, like an artificial carpeting. The rest of the water remains hanging on the ice, according to the warmth of the day. For when for a longer time it is warmer, the ice of the stalactites, of the walls and of the floor increases; but when the ruling heat, as sometimes happens, is diminished through north winds or rainstorm, the waters freeze more slowly, the ice drips more fully and begins to form little brooklets. When however the temperature gets warmer, the icy nature of the cave begins once more. Some have observed, that the nature of the grotto receives the changes of temperature ahead, like a barometer. For, when a warmer temperature sets in outside, the waters change into ice, several hours before the heat sets in, while the opposite takes place, when by day the temperature is colder; for then even by the warmest sky the ice begins to melt noticeably.

"When the dog days have passed and the summer has already changed into fall, the cave with its own nature follows the conditions of the external air. In the early months and while the nights are growing colder, the ice diminishes visibly; then when the air cools off more and

more and when the brooks and side are rigid with frost, it begins to melt as though there was a fire built underneath, until, when winter reigns, it is entirely dry in the cave, without a sign of ice being left behind. Then gentle warmth spreads into the entire cave, and this icy grave becomes a safety resort for insects and other small animals, which bear the winter with difficulty. But besides swarms of flies and gnats, troops of bats and scores of owls, hares and foxes take up their abode here, until with the beginning of spring, the cave once more assumes its icy appearance."

These assertions of Bel are the most inaccurate ones made about glacières. Yet, strange to say, they have colored the literature of the subject down to our own times; and have been repeated many times, sometimes with, sometimes without, the hares and foxes; the latest repetition seeming to occur in 1883.

CAVE NEAR THE VILLAGE OF BORZOVA, TORNA COUNTY, CARPATHIANS. (Fuggér, *Eishöhlen*, page 52.)—Reported to contain ice, but nothing certainly known.

CRIMEA.

LEDIANAIA YAMA. (Montpeyreux, *Voyage autour du Caucase* V., page 440; Hablizl, *Description physique de la Tauride*, 1783, pages 43–45.)—On the Karabi-Yaïla, 32 kilometers southwest of Karasubazar. Altitude about 1800 meters. A fairly large pit glacière cave. The name means an abyss of ice.

GLACIÈRE CAVE ON THE YAÏLA OF OULOUZÈNE AT KAZAUTÉ. (Montpeyreux, *Voyage autour du Caucase*, II., page 380.)—A small pit cave.

CAUCASUS.

GLACIÈRE CAVE IN THE KHOTEVI VALLEY. (Montpeyreux, *Voyage autour du Caucase*, II., page 379.)—In the province of Radscha, near the Monastery Nikortsminda. A large pit cave which must be of the same order as that of Chaux-les-Passavant and from which the inhabitants of Koutaïs get ice.

GLACIÈRES NEAR KOUTAÏS. (E. A. Martel, *Les Abimes*, page 397.)—"Dr. A. Sakharov, it appears, has recently discovered in the government of Koutaïs caves containing ice."

CAVE OF SABAZWINDA. (Fugger, *Eishöhlen*, page 126.)—Near the town of Zorchinwall, on the river Liachwa, province of Gori, in Georgia, near the Ossete Mountains. Ice has been found in the cave in summer. In December there was none.

URAL.

GLACIÈRE CAVE NEAR SUKEPWA. (Fugger, *Eishöhlen*, page 63.)—On the Volga, province of Zlatoust. Small cave on the river bank.

GLACIÈRE CAVE ON THE TIRMEN TAU. (Lepechin, *Tagebuch der Reise*, etc., vol. II., page 28.)—Near the village of Chaszina, 160 kilometers from Orenburg. Small cave.

GLACIÈRE CAVE OF KURMANAJEVA. (Lepechin, *Tagebuch der Reise*, etc., vol. II., page 5.)—Near Kurmanajeva, a village 49 kilometers from Tabinsk, in the Government of Orenburg. A large cave. Lepechin found ice in one part of the cave and deep water in another. There were draughts in some places.

CAVE ON THE BAISLAN TASCH. (Lepechin, *Tagebuch der Reise*, etc., II., page 40.)—The Baislan Tasch is a mountain on the right bank of the Bielaja River, which flows into the Kama. There is a large cave in the mountain in which ice has been found.

CAVE ON THE MUINAK TASCH. (Lepechin, *Tagebuch der Reise*, etc., II., page 38.)—The Muinak Tasch is a mountain on the Bielaja River. There is a large cave in it, in which a little ice has been found.

CAVE OF KUNGUR. (Lepechin, *Tagebuch der Reise*, etc., II., page 137; Rosenmüller and Tilesius, I., page 79.)—The Cavern of Kungur is near the town of Kungur in the Government of Perm. There are in it many passages and grottoes connecting with one another, some of which contain ice. It is a fine, large cave, whose greatest length is 400 meters.

MINES OF KIROBINSKOY. (Fugger, *Eishöhlen*, page 65.)—These mines are 53 kilometers southeast of Miask in the Ural; they have been abandoned. One of them contains ice all the year round.

CAVES OF ILLETZKAYA-ZATSCHITA. (Murchison, Vernieul and Keyserling, *The Geology of Russia in Europe and the Ural Mountains*, 1845, vol. I., page 186.)—72 kilometers southeast from Orenburg. The caves are in the Kraoulnaï-gora, a gypsum hillock 36 meters high, rising in the midst of an undulating steppe, which lies on a vast bed of rock salt. Only one of the caves contains ice. There are strong draughts in places.

SIBERIA

CAVE NEAR THE FORTRESS KITSCHIGINA. (Fugger, *Eishöhlen*, page 66.)—A small cave, 17 kilometers east of Kajilskoi, 192 kilometers from Petropaulowsk, 605 kilometers from Tobolsk. The cave is in an open plain, and sometimes contains ice.

WRECHNEJA PETSCHERA. (Fugger, *Eishöhlen*, page 66.)—Near the village Birjusinska, in the neighborhood of Krasnojarsk, on the right bank of the Yenisei. Large glacière cave.

GLACIÈRE CAVE OF BALAGANSK. (Fugger, *Eishöhlen*, page 66.)—A narrow cleft, 80 meters long; 192 kilometers downstream from Irkutsk on the left bank of the Angora River; at a distance of 2 kilometers from the river.

GLACIÈRE CAVE ON THE ONON RIVER. (Fugger, *Eishöhlen*, page 66.)—A small cave; 48 kilometers from the Borsja Mountain.

MINES OF SIRANOWSK. (Fugger, *Eishöhlen*, page 126.)—In the Altai Mountains, on the Buchtormà River, an affluent of the Irtysch. Magnificent ice formations have been found in these mines.

MINES OF SEVENTUI. (Fugger, *Eishöhlen*, page 126.)—Near Nertschinsk, on the Amoor River. Two of the levels contain perennial ice and hence are called *Ledenoi*. These are at a depth of about 60 meters in porous lava. The rest of the mine is in more solid rock.

GLACIÈRE CAVE NEAR LURGIKAN. (Fugger, *Eishöhlen*, page 67.)—Near the confluence of the Lurgikan and Schilka Rivers, in the province Nertschinsk. From 2 meters to 7 meters wide. Length 280 meters.

BASINS OR TROUGHS RETAINING ICE. (Dittmar, *Ueber die Eismülden im Östlichen Siberien;* Middendorff, *Zusatz; Bulletin de la classe physico-mathématique de l'Académie Impériale des Sciences de St. Petersbourg*, 1853, vol. XI., pages 305–316.)—These troughs are nearly akin to gorges and gullies, but their water supply seems to come from a cause which is not usually present in gorges. Their principal observer, M. de Dittmar, thought that a cold and snowy winter would add materially to the supply of ice, but he also thought that a necessity to the existence of the ice in these troughs was an abundant water supply from a spring, whose temperature should be so high as not to freeze in winter. The cold is supplied by the

winter temperatures. Some of the most important are reported—

In the Turachtach Valley.

Near Kapitanskji Sasiek.

In the valley of the River Belvi.

In the valley of the River Antscha.

In the Kintschen Valley.

In the neighborhood of Kolymsk.

In the Werchojanski Mountains.

In the Stanowáj Mountains.

KONDOOZ.

Cave of Yeermallik. (Burslem, *A peep into Toorkisthan*, 1846, chaps. X., XI.)—In the valley of the Doaub, northwest of Kabul. The entrance is half way up a hill, and is about 15 meters wide and 15 meters high. This is a large cave, with many ramifications and galleries. In the centre of a hall far within, Captain Burslem found a mass of clear ice, smooth and polished as a mirror, and in the form of a beehive, with its dome-shaped top just touching the long icicles which depended from the jagged surface of the rock. A small aperture led into the interior of this cone, whose walls were about 60 centimeters thick and which was divided into several compartments. Some distance from the entrance of this cave there is a perpendicular drop of 5 meters. A short distance beyond this, in one of the halls, were hundreds of skeletons of men, women and children, in a perfectly undisturbed state, also the prints of a naked human foot and

the distinct marks of the pointed heel of an Afghan boot. The moollah, who was acting as guide, said the skeletons were the remains of seven hundred men of the Huzareh tribe who took refuge in the cave with their wives and children during the invasion of Genghis Khan, and who defended themselves so stoutly, that after trying in vain to smoke them out, the invader built them in with huge natural blocks of stone, and left them to die of hunger. Some of the Afghans said that the cave was inhabited by Sheitan, a possibility denied by the moollah who guided Captain Burslem, on the philosophical plea that the cave was too cold for such an inhabitant.

HIMÁLAYA.

GLACIÈRE CAVE OF AMARNATH. (Miss Mary Coxe of Philadelphia showed me a copy of a letter of Dr. Wilhelmine Eger describing a visit to this cave.)—It lies three days' journey from Pailgam in Kashmere, on the borders of Little Tibet. The altitude is evidently high as one crosses snow fields to get to it. A small path zigzagging up a grassy slope leads to the cave and is a stiff climb from the valley. The cave opens on the side of a mountain and has a large, almost square mouth at least as big as the floor area within. The floor of the cave is the continuation of the grass slope and slants upwards and backwards to the back wall, the only case of the kind so far reported. This cave is most curiously connected with religion. Dr. Eger says that there are two small blocks of ice in it which never melt. From time immemorial these

blocks of ice have been sacred to the Hindoos who worship them—as re-incarnations—under the names of Shiva and Ganesh. Dr. Eger saw offerings of rice and flowers on them. Thousands of pilgrims come every year at the end of July or beginning of August from all parts of India. Thousands of miles have been traversed and hundreds of lives laid down through this journey. Every year people die either before reaching the cave or after. The trip from Pailgam in Kashmere takes three days up and two days down, if one returns by a shorter route where the way is unsafe because of avalanches. So many have perished there that the pass is called "The Way of Death." This must be taken by one class of pilgrims, *Sardhas* or Holy Men, to complete the sacred circuit, but the Hindoos say any one dying on the pass will go straight to heaven.

ICICLES FORMED BY RADIATION. (General Sir Richard Strachey, *Geographical Journal*, 1900, vol. XV., page 168.)—On the Balch pass of the Balch range in Tibet, General Strachey, in 1848, saw icicles of which he says: "On the rocks exposed to the south were very curious incrustations of ice, icicles indeed, but standing out horizontally like fingers towards the wind. I was not able to understand how they were caused, nor can I tell why they were confined to particular spots. The thermometer stood at 41° [F.], and though the dew point at the time would probably have been below 32° [F.], and the cold produced by evaporation sufficient therefore to freeze water,

yet it is evident that no condensation could ever take place simultaneously with the evaporation. * * * It has since occurred to me that these icicles were formed by radiation. I found, subsequently, in a somewhat similar position, that a thermometer suspended vertically, and simply exposed to the sky in front of it, was depressed as much as 20° F. below the true temperature of the surrounding air. This result was, of course, due to the radiation through the extremely dry and rarefied atmosphere at the great elevation at which the thermometer was exposed. As radiation takes place freely from a surface of ice, the growth of such icicles as those described might be due to the condensation of vapour brought up by the southerly day winds that so constantly blow over these passes, and its accumulation in the form of ice on the exposed extremity of the icicle, the temperature of which might thus have been greatly reduced."

INDIA.

Ice Formed by Radiation. (T. A. Wise, *Nature*, vol. V., page 189; R. H. Scott, *Elementary Meteorology*, Third Ed., pages 61, 62.)—Mr. Bunford Samuel called my attention to the mode of manufacturing ice by radiation in India. It is as follows:—

"A very practical use of nocturnal radiation has been made from time immemorial in India in the preparation of ice, and on such a scale that about 10 tons of ice can be procured in a single night from twenty beds of the dimensions about to be given, when the temperature of

the air is 15° or 20° [F.] above the freezing point. * * * The locality referred to is the immediate neighborhood of Calcutta. A rectangular piece of ground is marked out, lying east and west, and measuring 120 by 20 feet. This is excavated to the depth of two feet and filled with rice straw rather loosely laid, to within six inches of the surface of the ground. The ice is formed in shallow dishes of porous earthenware, and the amount of water placed in each is regulated by the amount of ice expected.

"In the cold weather, when the temperature of the air at the ice fields is under 50°, ice is formed in the dishes. The freezing is most active with N. N. W. airs, as these are driest; it ceases entirely with southerly or easterly airs, even though their temperature may be lower than that of the N. N. W. wind.

"No ice is formed if the wind is sufficiently strong to be called a breeze, for the air is not left long enough at rest, above the bed, for its temperature to fall sufficiently, by the action of radiation.

"The rice straw, being kept loose and perfectly dry, cuts off the access of heat from the surface of the ground below it, and, when the sun goes down, the straw being a powerful radiator, the temperature of the air in contact with the dishes is reduced some 20° below that prevailing some two or three feet above them. The rapid evaporation of the water into the dry air above creates also an active demand for heat to be rendered latent in the formation of steam, and the result of all these agencies is the

formation of ice, under favorable circumstances, on the extensive scale above mentioned."

KOREA.

GLACIÈRE CAVE ON THE HAN GANG.—Messrs. J. Edward Farnum and George L. Farnum, of Philadelphia, inform me that they saw a small cave containing ice on the banks of one of the Korean rivers. It is about 75 kilometers from Seoul, nearly northeast, near the ferry where the old road leading from Seoul towards northern Korea crosses the Han Gang, the river which passes by Seoul. The entrance is small; perhaps 2 meters wide. The cave is not thoroughly explored. Ice lies near the entrance, and as far back as the Messrs. Farnum could see.

JAPAN.

GLACIÈRE LAVA CAVE NEAR SHOJI. (*Evening Telegraph, Philadelphia, January 2d, 1896.*)—The cave is about 12 kilometers from Shoji, and is in lava. First there is a pit in the forest, some 5 meters wide by 15 meters deep. The cave opens into this. It seems to be some 400 meters long and from 2 meters to 12 meters high. There is an ice floor in places, also many ice stalagmites. At the furthest point reached there is a strong air current, which extinguishes torches and so far has prevented further exploration. Ice from the cave has been cut by the country people for sale at Kofu, which is not far distant.

PART IV.

SOME OPINIONS ABOUT GLACIÈRES.

SOME OPINIONS ABOUT GLACIÈRES.

Benigne Poissenot, in 1586, hinted that the cold of winter produced the ice at Chaux-les-Passavant.[69]

Reichard Strein and Christoph Schallenberger visited the caves on the Ötscher in 1591.[70]

Gollut, in 1592, suggested the cold of winter as the cause of the ice at Chaux-les-Passavant.[71]

In the *Histoire de l'Académie Royale des Sciences*, 1686, Tome II., pages 2, 3, there is an account, with no author's name, of Chaux-les-Passavant. The memoir states that in winter the cave is filled with thick vapors and that after some trees were cut down near the entrance, the ice was less abundant than formerly: that people come for ice with carts and mules, but that the ice does not become exhausted, for one day of great heat forms more ice than could be carried away in eight days in carts and wagons: and that when a fog forms in the cave, there is assuredly rain the following day, and that the peasants in the neighborhood consult this curious "almanac" to know the weather which is coming.

[69] See Part III.: page 193.
[70] See Part III.: page 231.
[71] See Part III.: page 202.

Freiherr Valvasor, in 1689, wrote about some of the glacières of the Krain.[72]

Behrens, in 1703, thought it was colder in summer than in winter in the caves near Questenberg in the Harz.

M. de Billerez, in 1712, writes that at Chaux-les-Passavant it is really colder in summer than in winter; and that the ice is harder than river ice, and this he thinks is due to the presence of a nitrous or ammoniacal salt, which he says he found in the rocks.

M. de Boz made four trips to Chaux-les-Passavant on the 15th of May and 8th of November, 1725; and the 8th of March and 20th of August, 1726. His memoir says that his observations tend to disprove those of M. de Billerez, and that "the cause for the great cold, which is less great in summer, although always remaining, is quite natural." He cites as causes for the ice the exposure to the north-north-east; the rock portal sheltering the entrance, and all the forest covering the surrounding lands; and adds that some veracious persons told him that since some of the big trees above the grotto had been cut down there was less ice than before. He found no traces of salt, nor any springs, and that the water supply came from the rains and melted snows filtering through the ground.

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[72] See Part III.: pages 238, 239.

In 1739, Matthias Bel published his curious account of Szilize.[73]

J. N. Nagel, a Vienna mathematician, visited the Ötscher in 1747. He concluded that the ice was made in winter and preserved in summer as in an ice house.

M. de Cossigny wrote, in 1750, about Chaux-les-Passavant. He made a plan of the cave and took many observations in April, August and October, and concluded that the interior condition of the cave does not change noticeably from winter to summer, no matter what the external conditions of temperature may be; that what people say of greater cold in summer, vanishes before actual experience and that, as a state of freezing reigns more or less continuously in the cave, it is not surprising if the ice accumulates. Apparently he was the first to notice and insist on the necessity of drainage to the cave through cracks in the rocks. He also made a series of observations disproving those of M. de Billerez, as to the presence of any kinds of salts in the rocks or ice.

Hacquet, in 1778, thought that the ice in the cave at Lazhnagora formed in winter, but he also thought that there must undoubtedly be some salt in the water. He says he found ice in the cave in the spring, and that his companion, a priest, had never found any in winter. He therefore concluded that by that time it had all melted.

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[73] See Part III. : page 254.

Romain Joly, in 1779, claims to have visited Chaux-les-Passavant on the 19th of September (year not given). His account seems largely borrowed from the one in the *Histoire de l'Académie Royale des Sciences*, in 1686. He says: "This ice is formed by the drops of water which fall from the roof, and which freeze because of the chill of the cave. In the winter there is no ice, but running water." He says nothing, however, about the ice forming in summer.

The *Citoyen* Girod-Chantrans visited Chaux-les-Passavant in August, 1783, and reached the conclusion, from all he saw and heard, that the cave did not freeze in summer nor thaw in winter, and that it was really a natural ice house. He was aided by the notes of a neighboring physician, Dr. Oudot, who had made observations in the cave, and among others, had placed stakes of wood, on the 8th of January, 1779, in the heads of the columns he had found in the cave; and on the 22d of February, 1780, had found these stakes completely covered with ice, forming columns 30 centimeters in diameter.

Hablizl, in 1788, wrote that the ice in the cave near Karassoubazar formed in the spring by the snows which melt, run into the cave, and refreeze. He also thought that there was less ice there in the fall than in the spring, that it diminishes in July and August, and that the idea, current in the neighborhood, of the formation of ice in summer, is a mistake.

Professor Pierre Prévost, in 1789, gave an accurate explanation of the formation of the ice in Chaux-les-Passavant. He says: "Weighing carefully the local circumstances, one discovers in truth a few causes of permanent cold. But these causes seem rather suited to keep up a great freshness or to diminish the heat of summer, than to produce a cold such as that which reigns in the cavern. First of all, big trees throw shade over the entrance; it is, I was told, forbidden under severe penalties to cut down any of them, for fear of depriving the grotto of a necessary shelter. In the second place, this entrance is situated almost due north, leaning a little to the east, which is the coolest exposure one can choose, and the one most suited to help the effect of the icy winds which blow from that quarter. Finally the slope is steep and the grotto deep and covered with a thick vault. These three conditions united constitute, as it seems to me, a very good *ice house;* by which I mean a reservoir fit to preserve during the summer, the ice which may bank up in winter.

"But how does this ice bank up? One knows that the outside waters above form on the roof, during the winter, long drops and stalactites of ice. These icicles, which hang down and increase constantly by the drip from the same source which formed them, fall at last, carried away by their own weight, and form so many centres, around which freeze the waters with which the floor of the grotto is always inundated. At the same time, the blowing of the north wind accumulates snow at the base of the slope, which is uncovered in part and exposed above to all the

vicissitudes of the weather. Thus during the winter is formed an irregular heap of ice and snow, which the first heats of spring begin to make run, but which the heats of summer cannot finish dissolving. The winter following has therefore even more facility to augment the mass of these ice pyramids, which have resisted until the fall. And if men did not work at diminishing it, it might happen that it would fill the entire cavern at last to a great height.

"I am therefore strongly inclined to think that the process of nature is here precisely similar to that of art; that without any especial cause of cold, the natural glacière of Besançon conserves in the moderate temperature of deep caverns, the heaps of snow and ice which the winds and the outside waters accumulate there during the winter; and that the melting of these snows and of these accumulated ices forms little by little the ice floor, scattered over with blocks and pyramids, which one observes there during the summer."

Horace Bénedict de Saussure, the great Swiss scientist and mountaineer, in 1796, published a number of observations about cold current caves in various parts of the Alps. He found that in summer the air blows outward at the lower end, and that in winter it draws inward. His explanation is that in summer the colder air in the tube is heavier than the outside air and displaces it by gravity; while in winter the rupture takes place in the other direction, since the column within the tube is warmer than the outside air and therefore is pushed upwards by the heavy

air flowing in. He concludes that evaporation due to the air passing internally over moist rocks suffices to explain the phenomenon of low temperatures and that such caves have a rather lower temperature in the Alps than in Italy owing to the greater natural cold of the Swiss lake region. An experiment of his is worth mentioning. He passed a current of air through a glass tube, 2.5 centimeters in diameter, filled with moistened stones, and found that the air current which entered with a temperature of 22.5° came out with a temperature of 18.75°, that is with a loss of 3.75° of heat.

Robert Townson, LL. D., in 1797, published an account, perhaps the first in English, of a glacière cave. He says of Szilize: "Ice I truly found here in abundance, and it was midsummer, but in a state of thaw; the bed of ice, which covered the floor of the cavern was thinly covered with water and everything announced a thaw. I had no need to use my thermometer: however I placed it in the ice and it fell to 0° of Réaumur: I then wiped it and placed it in a niche in the rock, at the furthest part of the cavern, a yard above the ice and here it remained near an hour: when I returned I found it at 0°. * * * Everything therefore, ice, water and atmosphere in the neighborhood had the same temperature, and that was the temperature of melting ice: 0° Réaumur.

"When then is the ice which is found here, and in such quantities that this cavern serves the few opulent nobility in the neighborhood as an ice house, formed?

Surely in winter, though not by the first frost, not so soon as ice is formed in the open air. No doubt, from the little communication this cavern has with the atmosphere, it will be but little and slowly affected by the change. Should therefore, Mr. Bel, or any of his friends, have come here to verify the common report at the commencement of a severe frost, when the whole country was covered with ice and snow, they might still have found nothing here but water, or the ice of the preceding winter in a state of thaw, and the cavern relatively warm; and likewise, should they have visited it in a warm spring, which had succeeded to a severe winter, they might have found nothing here but frost and ice; and even the fresh melted snow, percolating through the roof of this cavern, might again have been congealed to ice. I observed frequently in Germany in the severe winter of 1794–5, on a sudden thaw, that the walls of churches and other public buildings, on the outside were white and covered with a hoar frost, and the windows on the same side covered with a rime."

Dr. Franz Sartori, in 1809, was a strong believer in the summer ice theory, and wrote of the flies and the gnats, the bats and the owls, and the foxes and the hares coming to Szilize to winter.

Alexander von Humboldt, in 1814, says about the Cueva del Hielo on the Peak of Teneriffe that so much snow and ice are stored up in winter that the summer heat

cannot melt it all, and also adds that permanent snow in caves must depend more on the amount of winter snow, and the freedom from hot winds, than on the absolute altitude of the cave.

Dewey, in 1819, thought that the ice in the Snow Glen at Williamstown was a winter formation.

Professor M. A. Pictet visited Saint-Georges, Le Brezon and Montarquis and in 1822 endeavored to prove that they are cold current caves and that the ice in them is due entirely to draughts causing evaporation. He believed in the theory of the ice forming in summer more than in winter and that it could not be the residue of a winter deposit. He therefore argued that it must be due to descending currents of air which he thought would be most energetic in summer; that they would become at least as low as the mean annual temperature of the place and be still further cooled by evaporation. The strange thing about his theories is that he does not seem to have personally observed any draughts either at Saint-Georges or Le Brezon, but the fact that the ice was evidently not an accumulation of winter snow led him to try to reconcile what he had himself seen with de Saussure's theories about windholes.

Jean André Deluc in 1822 published a paper discussing the theories of MM. de Cossigny, Prévost and Pictet. Deluc had never visited a glacière himself, but he explains clearly the impossibility of Professor Pictet's cold current

theory, on the simple ground that Professor Pictet himself did not find any cold currents. He takes up Professor Prévost's theories warmly; using also the manuscript notes of Mons. Colladon who had visited the Grand Cave de Montarquis. Deluc says: "that the winter's cold penetrates into these caves, freezes the water which collects there and that the ice thus formed has not the time to melt during the following summer." He says further: "It seems that in the three glacières with which we have been occupied there is a flat or rather hollow bottom, where the waters can form a more or less deep pond, and whence they therefore cannot flow away; it is there they flow in winter; and as these are shut in places where the air cannot circulate, the heats of summer can only penetrate very feebly. The ice once formed in such cavities, only melts slowly; for one knows that ice in melting, absorbs 60° of heat; and where find this heat in an air always very cold and nearly still? During a great cold, the ice forms with great promptness, while it melts with much slowness, even when the temperature of the air is several degrees above zero; what must then not be this slowness when the temperature of the interior air only rises in summer one degree above freezing point. It would need several summers to melt this ice if it did not reform each winter."

C. A. Lee, in 1825, wrote that the ice in the Wolfs-hollow near Salisbury was a winter formation.

G. Poulett Scrope, in 1826, accepted as the truth the statement that the cave of Roth was filled with ice in

summer, but that it was warm during the winter. In 1827, he explained the presence of ice at Pontgibaud as follows: "The water is apparently frozen by means of the powerful evaporation produced by a current of very dry air issuing from some long fissures or arched galleries which communicate with the cave, and owing its dryness to the absorbent qualities of the lava through which it passes."

F. Reich, in 1834, thought that there were two possible causes which might produce subterranean ice: 1, the difference in specific gravity between warm and cold air; 2, evaporation. He thought the cold air a sufficient cause in most caves, but he considered that evaporation also played a part not infrequently.

Professor Silliman, in 1839, gave the first hint, in the negative, about compressed air as a cause for subterranean ice. He said about Owego that if one could suppose that compressed gases or a compressed atmosphere were escaping from the water or near it, this would indicate a source of cold, but that as there is no indication of this in the water, the explanation is unavailable.

Professor A. Pleischl wrote in 1841 that he was told that ice formed on the Pleschiwetz and on the Steinberge in summer. Continuing, he says: "The author is therefore, as well as for other reasons, of the opinion, that the ice is not remaining winter ice, but a summer formation, and one formed by the cold of evaporation. * * * The basalt is, as a thick stone, a good conductor

for the heat, and takes up therefore easily the sun's warmth, but parts with it easily to other neighboring bodies. In the hollows, between the basalt blocks, is found, as I already mentioned, rotting moss, which forms a spongy mass, which is wet through with water. The basalt heated by the sun's rays now causes a part of the water in the spongy mass to vaporize; for this evaporation the water needs heat, which it withdraws from the neighboring bodies and in part from water, and makes the water so cold, that it freezes into ice, as, under the bell of an air pump—Nature therefore makes here a physical experiment on the largest scale."

Much stress appears to have been laid on the paper of Professor Pleischl by Professor Krauss and one or two others. The weak point in it is that Pleischl did not see the ice form in summer, but was only, as usual, told that it did so. There is nothing in the facts given to show that the places mentioned are different from any other taluses, where ice does not form as the result of heat.

Mr. C. B. Hayden, in 1843, wrote about the Ice Mountain in Virginia, and held that the porous nature of the rocks makes them poor conductors of heat, and that the mountain is a huge sandstone refrigerator.

Dr. S. Pearl Lathrop, in 1844, wrote of the Ice Bed at Wallingford, Vermont, as a great natural refrigerator.

Sir Roderick Impey Murchison wrote in 1845 about the salt mine and freezing cave of Illetzkaya-Zatschita.

He visited them during a hot August, and was assured that the cold within is greatest when the external air is hottest and driest; that the fall of rain and a moist atmosphere produce some diminution in the cold of the cave and that on the setting in of winter the ice disappears entirely. He accepted these statements evidently only in a half hearted way, submitting them to Sir John Herschel, who tried to explain them, in case they were true, of which Herschel was likewise doubtful. Murchison at first thought that the ice was due to the underlying bed of salt, but soon recognized that this explanation could not be correct. He also rejected Herschel's "heat and cold wave" theory. Shortly after this he came across Pictet's memoir, and on the strength of it concluded that the ice in Illetzkaya-Zatschita could not be the residue of a winter deposit, but must be due to descending currents of air; to the previously wet and damp roof affording a passage to water; and to the excessive dryness of the external air of these southern steppes contributing powerfully to the refrigerating effects of evaporation.

Professor Arnold Guyot, in 1856, said that the well at Owego admitted large quantities of snow which melts, but not readily, because it is not accessible to the sun. It therefore goes through the same process as glaciers, of partly melting and refreezing; and we have the formation of a glacier without movement.

Professor W. B. Rogers, in 1856, held that the well at Owego became the recipient of the coldest air of the

neighborhood, and the temperature remained abnormal because the bad conducting power of the materials of the well retained the cold.

Professor D. Olmstead, in 1856, held about Owego that cold air exists in the interior of the earth which may have found a ventilating shaft in the well.

Professor Petruzzi, in 1857, considered the following requirements necessary for a glacière: A high altitude above the sea; a decided drop into the interior of the mountain; absence of all draught; protection against all warm and moist winds, therefore the opening to north and east. He also says about the glacière on the Pograca: that it is in shadow; that the thick forest round the mouth keeps the temperature down; that it begins to freeze below when it does above; that the cold remains there into the spring; and that the water from rain or other sources, which flows into the cave, must freeze there, and the ice form in greater quantities than the heat of summer can melt away.

Mr. Albert D. Hager wrote in 1859: "The question now arises, why it was that such a congealed mass of earth was found in Brandon at the time the frozen well was dug. My opinion is, that the bad conducting property of the solids surrounding it, the absence of ascending currents of heated air, and of subterranean streams of water in this particular locality favored such a result; and

that the bad conducting property of clay, as well as that of the porous gravel associated with it, taken in connection with the highly inclined porous strata, and the disposition of heated air to rise, and the cold air to remain below, contribute to produce in the earth, at this place, a *mammoth refrigerator*, embracing essentially the same principle as that involved in the justly celebrated refrigerator known as 'Winship's Patent.'

"Clay is not only nearly impervious to air and water, but it is one of the worst conductors of heat in nature. (NOTE.—To test the question whether clay was a poor conductor of heat or not, I took two basins of equal size, and in one put a coating of clay one-half inch thick, into which I put water of a temperature of 52° Fahrenheit. Into the other dish, which was clean, I put water of the same temperature, and subjected the two basins to equal amounts of heat; and in five minutes the water in the clean dish indicated a temperature of 70° while that of the one coated with clay was raised only to 56°.) If we can rely upon the statements of those who dug out the frozen earth, it rested upon a stratum of clay that lay upon the bed of pebbles in which the water was found, for it was described as being a very sticky kind of hard pan.

"This being the case, if the water contained in the pebbly mass had a temperature above the freezing point, the heat would be but imperfectly transmitted to the frost, through the clay, provided there was no other way for its escape. But we have seen that the stratum of clay that overlays the bed of pebbles in the side of the gravel pit

was not horizontal, but inclined towards the well at an angle of 25°. Now if this drip was continued to the well, and existed there (which is highly probable), it will be seen that the ascending current of heated air, in the pebbly bed, would be checked upon meeting the overlying barrier of clay and be deflected out of its upward course. The tendency of heated air is to rise, hence it would continue its course along the under side of the clay, through the interstices in the bed of pebbles, till it found a place of escape at the surface, which in this case may have been at the gravel pit before named."

Professor Edward Hitchcock wrote in 1861: "The presence of a mass of frozen gravel deep beneath the surface in Brandon, was first made known by digging a well in it in the autumn of 1858. * * * The gravel, also, rises into occasional knolls and ridges. In short, it is just such a region of sand and gravel as may be seen in many places along the western side of the Green Mountains; and indeed, all over New England. It is what we call modified drift, and lies above genuine drift, having been the result of aqueous agency subsequent to the drift period. * * * The well was stoned up late in the autumn of 1858, and during the winter, ice formed upon the water in one night, two inches thick. It continued to freeze till April; after which no ice was formed on the surface, but we can testify that as late as June 25th, the stones of the well for four or five feet above the surface of the water were mostly coated with ice; nay, it had not

wholly disappeared July 14th. The temperature of the water was only one degree of Fahrenheit above freezing point. The ice did however disappear in the autumn but was formed again (how early we did not learn) in the winter, and so thick too that it was necessary to send some one into the well to break it. We visited the well August 18th, 1860, and found the temperature 42°. Yet only the week previous ice was seen upon the stones, and we were even told by one of the family, that a piece of ice had been drawn up the day before in the bucket. * * * These frozen deposits may have been produced during the glacial period that accompanied the formation of drift, and continued far down into the subsequent epochs of modified drift. * * * But in all the excavations both gravel and clay occur: and how almost impervious to heat must such a coating 20 feet thick, be! It would not, however, completely protect the subjacent mass from solar heat. But there is another agency still more powerful for this end, namely, evaporation, which we think has operated here, as we shall more fully describe further on; and we think that these two agencies, namely, non-conduction and evaporation, may have preserved this frozen deposit for a very long period, from exterior influences."

Professor Thury in 1861 says about Saint-Georges: "Such is the *résumé*, concise but exact, of the results of our winter excursion. They furnish proof to the fact generally borne witness to by the mountaineers, that ice does not form in winter in the interior of caverns. But if this

is so, it is for a very simple reason: two things are necessary for the formation of ice: cold and water. In winter, the cold is not wanting: but if there is no spring opening in the cave, the water is absent, and then no ice forms.

"It is in the spring, at the time of the first melting of the snows, that the ice must form. Then water at 0° pours over the surface, and penetrates by the fissures of the rock and by the large openings into the chilled cavern, which is also receiving the freezing air of the nights. The grotto then makes its annual provision of ice, which after this could only diminish little by little during the whole duration of the warm season."

Professor Thury writes about the Grand Cave de Montarquis: "Here it must be when water and cold meet, that is autumn and especially spring, the time of the first melting of the snows."

"During the winter * * * the colder, heavier air comes to freeze the water of the grotto, and chill the ice and the wall of rock."

"During the summer, the radiation of the vaults and the proper heat of the ground only melt a small quantity of ice because this absorbs much heat to pass into a liquid state."

"The heat of the air is entirely used to melt the ice; it does not therefore manifest itself as sensible heat."

"The contact of the ice ready to melt, plays in a certain way, towards the air a little warmer than itself, the rôle of an extremely absorbing body, or one which has an excessive caloric conductibility."

"Here the formation of the ice could not possibly be attributed to the cold caused by evaporation. The psychrometer indicated ninety-two per cent. of relative humidity: the atmosphere of the grotto was therefore almost saturated with evaporation of water, and the maximum of cold caused by evaporation was not over half a degree centigrade."

About prismatic ice and a hollow pyramid, he says: "The prismatic (*aréolaire*) structure is produced later on in the ice, by a new and particular arrangement of the molecules of the already solidified water. Therefore the recent stalactites are never crystallized."

"In the beginning of the hot season, the atmospheric temperature of the grotto rises slowly. Inferior to zero by some tenths of a degree, it produces first on the surface, in the stalactites, the prismatic structure. The temperature continues to rise, the central portions of the stalactites, still composed of ordinary ice, liquefy, and if the melting water finds some issue, either by accidental openings left between some prisms, or by the extremity of the stalactite or by some point of its surface which had escaped the action of the regular crystallization; by this opening the water escapes, and the tubular stalactite has been formed."

"The column was composed of a very special ice, perfectly dry, perfectly homogeneous, translucid and whose appearance could only be compared to that of the most beautiful porcelain. I am inclined to believe that we had under our eyes a special molecular state of congealed water. This state would be produced under the influence

of a constant temperature of a certain degree (NOTE—perhaps not far from 4°—the actual temperature of the grotto) long prolonged. These causes can he realized more completely in glacierès than anywheres else."

The Reverend George Forrest Browne, published in 1865, *Ice Caves in France and Switzerland*, one of the most delightful books of travel ever written, on account of the scientific accuracy and the humor of the author. He visited La Genollière, Saint-Georges, Saint-Livres, Chaux-les-Passavant, Monthézy, Arc-sous-Çicon, the Schafloch, Haut-d'Aviernoz, which he calls Grand Anu, Chapuis, and Font-d'Urle. He says: "The view which Deluc adopted was one which I have myself independently formed. * * * The heavy cold air of winter sinks down into the glacières, and the lighter warm air of summer cannot on ordinary principles of gravitation dislodge it, so that heat is very slowly spread in the caves; and even when some amount of heat does reach the ice, the latter melts but slowly, for ice absorbs 60° C. of heat in melting; and thus, when ice is once formed, it becomes a material guarantee for the permanence of cold in the cave. For this explanation to hold good it is necessary that the level at which the ice is formed should be below the level of the entrance to the cave; otherwise the mere weight of the cold air would cause it to leave its prison as soon as the spring warmth arrived. In every single case that has come under my observation, this condition has been emphatically fulfilled. It is necessary, also, that the cave should be protected from direct

radiation, as the gravitation of cold air has nothing to do with resistance to that powerful means of introducing heat. This condition, also, is fulfilled by nature in all the glacières I have visited, excepting that of S. Georges; and there art has replaced the protection formerly afforded by the thick trees which grew over the hole of entrance. The effect of the second hole in the roof of this glacière is to destroy all the ice which is within range of the sun. A third and very necessary condition is, that the wind should not be allowed access to the cave; for if it were, it would infallibly bring in heated air, in spite of the specific weight of the cold air stored within. It will be understood from my description of such glacières as that of the Grand Anu, of Monthézy, and the lower glacière of the Pré de S. Livres, how completely sheltered from all winds the entrances to those caves are. There can be no doubt, too, that the large surfaces which are available for evaporation have much to do with maintaining a somewhat lower temperature than the mean temperature of the place where the cave occurs."

Browne noticed prismatic ice several times. He says of it: "M. Thury suggests also, as a possibility, what I have found to be the case by frequent observations, that the prismatic ice has greater power of resisting heat than ordinary ice. * * * A Frenchman who was present in the room in which the Chemical Section of the British Association met at Bath, and heard a paper which I read there on this prismatic structure, suggested that it was probably something akin to the rhomboidal form assumed

by dried mud; and I have since been struck by the great resemblance to it, as far as the surface goes, which the pits of mud left by the coprolite workers near Cambridge offer, of course on a very large scale. This led me to suppose that the intense dryness which would naturally be the result of the action of some weeks or months of great cold upon subterranean ice might be one of the causes of its assuming this form, and the observations at Jena would rather confirm than contradict this view: competent authorities, however, seem inclined to believe that warmth, and not cold, is the producing cause."

Mr. Browne found a hollow cone at La Genollière, for which he accounted as follows: "In the loftier part of the cave * * * ninety six drops of water in a minute splashed on to a small stone immediately under the main fissure. This stone was in the centre of a considerable area of the floor which was clear of ice. * * * I found that the edge of the ice round this clear area was much thicker than the rest of the ice on the floor, and was evidently the remains of the swelling pedestal of the column. * * * When the melted snows of spring send down to the cave, through the fissures of the rock, an abundance of water at a very low temperature and the cave itself is stored with the winter's cold, these thicker rings of ice catch first the descending water, and so a circular wall, naturally conical, is formed around the area of stones; the remaining water either running off through the interstices, or forming a floor of ice of less thickness, which yields to the next summer's drops. In the course

of time, this conical wall rises, narrowing always, till a dome-like roof is at length formed and thenceforth the column is solid." From what I have observed myself, this explanation seems to fairly meet the facts.

Professor T. G. Bonney, in 1868, was inclined to believe that there was some connection between glacières and a glacial period.

Mr. W. R. Raymond, in 1869, concluded from his own observations about the lava cave in Washington: that the cold air of winter freezes up the percolating waters from the surface, layer upon layer, solid from the bottom, and the accumulated ice thaws slowly in summer, being retarded by the covering which keeps out the direct rays of the sun, and by the fact that the melting ice at one end of the cave, through which the summer draught enters, itself refrigerates the air and maintains a freezing temperature at the other end.

Dr. C. A. White, in 1870, says of the cavern at Decorah: "The formation of the ice is probably due to the rapid evaporation of the moisture of the earth and rocks, caused by the heat of the summer sun upon the outer wall of the fissure and valley side. This outer wall is from ten to twenty feet in thickness where the ice was seen to be most abundant. The water for its production seems to be supplied by slow exudation from the inner wall of the cave."

Dr. Krenner, in 1874, wrote of Dóbsina as "a natural ice cellar of giant dimensions, whose ice masses formed in winter, the summer does not succeed in melting."

Professor W. Boyd Dawkins wrote in 1874: "The apparent anomaly that one only out of a group of caves exposed to the same temperature should be a glacière, may be explained by the fact that these conditions [those formulated by the Rev. G. F. Browne] are found in combination but rarely, and if one were absent there would be no accumulation of perpetual ice. It is very probable that the store of cold laid up in these caves, as in an ice house, has been ultimately derived from the great refrigeration of climate in Europe in the Glacial Period."

Mr. Theodore Kirchhoff examined the lava caves in the State of Washington and in 1876 wrote that he considered that the ice in the smaller ones were simply remains of the winter's cold. He thought that the ice in the large cave where there is a draught could not be accounted for in the same way, so he concluded that the ice must be due to the draught.

Mr. N. M. Lowe, in 1879, proposed the Compressed Air or Capillary theory[74] about the Cave at Decorah.

Mr. John Ritchie, Jr., in 1879, gave an exceedingly clear exposition of the theory in the same journal.

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[74] See Part II., page 142.

Mr. Aden S. Benedict, in 1881, published his observations about Decorah. He found that there was no water falling in the cave to compress the air, that there was no water falling near enough to be heard, nor any aperture giving vent to cold air in the cave. He thought that the cold of winter cools the sides of the cave several degrees below freezing point and that these rocks are so far underground that it would take a long season of hot weather to raise this temperature to the melting point of ice. In the spring the water percolates through the soil and drips on to the yet freezing rocks; on which it freezes and remains until the heat of summer penetrates to a sufficient depth to melt it away. The rocks once raised above 0° remain so until the following winter and consequently if there are heavy autumn rains there is water on the rocks but no ice. Mr. Benedict concluded that there was nothing more mysterious about Decorah than the fact that if you drop water on a cold stone it will freeze.

Professor Friederich Umlauft in 1883 wrote about glacières "that as moreover they were generally protected against warm winds and strong draughts and as their entrances look towards the north or east, there is consequently more ice formed under these conditions in winter than can melt away in summer. Other ice grottoes however show the remarkable characteristic, that it is warm in them in winter, in the summer on the contrary it becomes so cold that all the dripping water freezes. They are found near snow clefts and gorges; when in the hot sum-

mer months the snow melts, then the cold which has become free presses down the temperature in the cave so much that the water freezes into ice. Such grottoes are in Austria at * * * Frauenmauer, * * * Brandstein, * * * Teplitz, * * * Scilize, * * * Dobschauer."

Herr Körber in 1885 wrote about the Schafloch, that the stored-up winter's cold stands out as permanent adversary of the higher temperature of the earth. The thermometer proved this by its action at the end of the cave in a rock cleft, which is warmer than the rest of the cave. In September Herr Körber found the masses of ice less and the stalagmites smaller than in January, especially a column which in January had become a stately mountain of transparent ice.

Professor Eberhard Fugger of Salzburg, has studied the caves of the Untersberg carefully, having paid over eighty visits to them. He classifies freezing caverns into the following types, according to their position and their shape:

According to position: 1, open caves, that is those whose entrance is free on a rock wall; 2, pit caves, where the entrance is at the bottom of a pit; 3, pit caves, where the pit is covered and the opening is in the roof.

According to shape: 1, *sackhöhlen* or chamber caverns, into which one enters immediately at the entrance; 2, *ganghöhlen*, or passage caves terminating in a chamber; 3,

röhrenhöhlen, or passage caves where the passages continue further than the chamber.

He is a strong advocate of the winter's cold theory. He says: "The ice of caves is formed by the cold of winter, and remains despite the heat of summer, as through local circumstances the quantity of heat brought to the ice is not great enough to melt it by the time when ice and snow in the open at the same altitude have already disappeared."

"In order that ice may form in a cave in winter, two factors are necessary. There must be water present in some form or other, and in some way the outside cold air must be able to sink into the cave."

"When the bottom of a cave is below the entrance, the outside cold winter air sinks into the cave from its weight, when the temperature of the cave air is higher than that of the outside air; and it will remain there during the warmer weather, as the warm outside air on account of its lighter weight cannot drive out the cold heavy cave air."

"The most important factor for the formation of ice is the drip water. The more drip flows into a cave during the cold season, the more ice is formed; the more drip, on the contrary, flows into the cave during the warm season, the more ice is destroyed."

"The warmth, which the roof of the cave gives out, is also a cause which helps to melt the ice, and a cause in fact which works the harder, the higher the temperature of the roof and the dirtier the ice floor."

"If direct rays of the sun penetrate a cave, they scarcely

warm up the air which they traverse, but they raise the temperature of the floor or of the walls, which they touch. They are therefore a very important factor, which may bring about the melting of the ice."

"The snow slope at the mouth of a cave offers some protection against the rays of the sun, especially if it is no longer white, but covered with all sorts of dirt."

"The larger the mass of ice, the longer is its duration."

"A certain thickness to the roof is of importance in preserving the ice. If it is less than 8 meters, then it is well if it is covered with outside vegetation."

I entirely agree with these *dicta* of Professor Fugger.

In 1893, Fugger writes: "The peculiar readings of temperature, which I made in August 1877, in the Kolowratshöhle, namely on the 13th at 12 M., 0.5°, on the 15th at 4 P. M., 0.35°, on the 23d at 10 A. M., 0.12°, on the 26th at 10 A. M., 0.17°, and on the 30th at 2.15 P. M., —0.10°, I think I can attribute to the workings of the winds. In the observations themselves there could scarce be an error. All five observations were made at the same place, with the same thermometer, after at least half an hour's exposure. In the time from the 13th to the 30th of August, the temperature minimum in the town of Salzburg, was 12°; before the 30th were several cloudless nights. During the whole of August scarcely any but southeast and northwest winds were blowing. The Kolowratshöhle opens in a rock wall to the east; the above named winds therefore affected during the entire month the entrance to the cave and may have produced a lively

evaporation in the cave, through a sort of sucking up of the cave air, and thus have created the rather decided cooling off of 0.6° within seventeen days."

This statement, coming from Professor Fugger, deserves particular attention, because it would go to show: first, that the air in the Kolowratshöhle, a *sackhöhle* with only one entrance, is only apparently stagnant in summer and not really so; and second, that evaporation may act to a limited extent in a cavern where there is almost no running water.

Captain Trouillet, in 1885, published a paper about Chaux-les-Passavant. He found that when it was colder inside than outside, the internal air was nearly cut off from the outside; when it was coldest outside there was a lively disturbance. He called these two classes *périodes fermées* and *périodes ouvertes*. He says: "The duration of a *closed period* is measured then on the curves [of a maximum and minimum thermometer] of the interior temperatures, between a minimum and the following maximum; that of an *open period* is between a minimum and the preceding maximum. One can thus count from the 25th November to the 31st December 25 *open periods* of a total duration of 200 hours or 8 times 24 hours: which gives for each a duration of 7½ hours. The shortest lasted 2 hours and the longest 16 hours. During the same interval, the *closed periods* numbered 26, making a total duration of about 28 days; the longest, which lasted from the 3d to the 8th December, was 126 hours long."

Trouillet also says: "From the 23d to the 30th December, the grotto was completely isolated from the external air, and yet during three consecutive nights, the interior had three marked chills. Such is the phenomenon whose cause can only lay, in our opinion, in the introduction of the dry air driven to the cave by the winds between north and east. This air on entering comes in contact with the ice and the humid roof of the cave; it saturates itself in producing a formation of vapors, and therefrom a consumption of heat which may be considerable."

There are some discrepancies in this last paragraph which must be noted, for the reason that Trouillet's observations are so valuable. He does not mention having seen the vapors himself, in fact the production of these vapors seems only an inference. Nor is it easy to understand how the grotto could be "completely isolated from the external air" if the phenomenon lay "in the introduction of the dry air driven to the cave by the winds north and east."

Dr. B. Schwalbe, in 1886, wrote that "all my observations point to the fact that the rock is the cooling factor in summer, and that the cold goes out from it." He says also that "when I saw for the first time the little cave of Roth, which was filled with fairly numerous ice formations, it was precisely the smallness of the volume of air and the strange appearance of the ice which made the simple cold air theory seen insufficient, nor could I later, by widening the theory and observing the localities from the basis of

DeLuc's theory, accept it. It always seemed by all my observations that in the rock there must be a lasting source of cold. There must be a cause present, which prevents the rapid warming of the cave wall through the temperature of the ground, which also keeps the stone cool in summer and induces the main ice formation in the spring." He also hints that Mr. Lowe's compressed air theory may be the correct one. Dr. Schwalbe's work, *Uber Eishöhlen und Eislöcher*, is one of the four or five most important contributions to glacière literature, and his opinion is entitled to great respect on account of his many observations.

Professor Israel C. Russell wrote in 1890, about the ice beds on the Yukon: "It is thought by some observers, to be an inheritance from a former period of extreme cold; but under existing climatic conditions, when ice forms beneath a layer of moss, it is preserved during the short summer, and may increase as it does on the tundras, to an astonishing thickness."

In 1897, Professor Russell says: "It is not probable that all the subsoil ice of northern regions has been formed in one way. Along the flood plains and on the deltas of rivers where layers of clear ice are interbedded with sheets of frozen gravel and vegetable matter, as is frequently the case, it seems evident that the growth of the deposit is due, in some instances, to the flooding of previously frozen layers, and the freezing and subsequent burial of the sediment thus added to their surfaces.

When spring freshets spread out sheets of débris over the flood plain of a river, as frequently happens when streams in high latitudes flow northward, the previously frozen soil and the ice of ponds and swamps may be buried and indefinitely preserved." "There is still another process by which frozen subsoil may be formed in high latitudes: this is, the effects of the cold during the long winters are not counteracted by the heat during the short summers. Under the conditions now prevailing in northern Alaska, where the mean annual temperature is below 32° Fahrenheit, the frozen layer tends to increase the thickness from year to year just as the depth of frozen soil in more temperate latitudes may increase from month to month during the winter season. During the short northern summers, especially where the ground is moss covered, melting only extends a few inches below the surface."

Mons. E. A. Martel, in 1892, wrote of the Creux-Percé: "I incline only, as in all the pits which narrow at the bottom (*avens à rétrécissement*) to attribute the chilling to the fall of the cold air of winter and to its non-renewal in summer." And at page 564 of *Les Abimes* he says: "One knows that *evaporation* is an active cause of cooling; therefore it is always cooler in caves near the drips of water. * * * I have positively noted this influence of evaporation near the drips of Tabourel (8° instead of 9.5°), of Dargilan, of the Cerna Jama, and in abysses with double mouths where there were strong draughts (Raba-

nel, Biau, Fosse-Mobile, etc.)." In December, 1897, Mons. Martel writes: "In short, the action of the winter's cold is the real cause accepted by * * * and recently confirmed by Fugger, Trouillet and Martel." And also: "It is probable that this influence [evaporation] is only real at rather high altitudes; this is at least what seems the result of the studies of the caves of Naye (1700 to 1900 meters) begun by Professor Dutoit."

In 1899, Mons. Martel gave an account of the Glacière de Naye. In this paper, he abandons definitely fossil ice, salts and the capillary theory as possible causes of underground ice. He considers that there are four causes: 1, shape of the cavity; 2, free access of snow in winter; 3, high altitude; 4, evaporation due to wind currents. The last two causes he thinks are not necessarily always present. For instance he considers that, at the Creux-Percé, and at Chaux-les-Passavant, the ice is due especially to the sack or hour-glass shape of these hollows where the summer air cannot get in on account of its lightness. At the Glacière de Naye, which is a big windhole, situated at an altitude of 1750 to 1820 meters, Mons. Martel thinks that the ice is formed by the snow and cold of winter, but that its preservation is assured by the evaporation caused by the action of the windhole.

Dr. Terlanday, in 1893, asserted that ice does not form in Szilize in winter, and that the ice first forms in the winter in the upper part of rock fissures and that in the spring, at the time of an increase of temperature, this

fissure ice is brought to the melting point by the successive entering of heat into the earth and that it then arrives at the cave, where it aids the formation of icicles. This theory about fissure ice is probably in so far correct, that the ice in the upper parts of fissures, near the surface of the ground, melts before the ice in the lower parts of fissures. The drip would then naturally run into the cave and, as long as the temperature of the cave was low, help to form cave ice.

Dr. Hans Lohmann, in 1895, published some valuable notes about several glacières. While considering the cold of winter as the main cause of the ice, he thought evaporation a secondary cause of cold. He says: "That the cold from evaporation bears its share in cooling a cave, will not be denied. * * * The air saturated with aqueous vapor makes one think of constant evaporation. The aqueous vapor spreads itself by diffusion throughout the entire cave, and if the outside air is driest, goes to that. Through this, more ice and water can always be vaporized, and to the warming elements there is furnished a cooling one. If dry winds get into the cave, then must evaporation be very lively and the chilling especially strong. Through this cause alone can be explained the remarkably low temperature of $+6.3°$ in the new part of the Garischen Stollen, in contrast to the temperature of $+7.9°$ in the old part. The strong draught in the last drew out through its suction the damp air of the new adit, so that there had to be a strong evaporation."

Dr. Lohmann gives some exhaustive notes about prismatic ice. He found it a product of the fall months. He thinks all the observations show that "the beginning of all prismatic formation in the ice may be looked for in the changes of temperature in the cave at the time of the formation of the ice. These cause the everywhere recognized splitting, vertically to the outer surface. The further development hangs, as shown by Hagenbach and Emden, on the attempt of the neighboring cells, to join into larger unities. The increase of the larger crystals is finally prevented by the melting out of the openings between the separate crystals. Through this may be explained the difference in the prismatic ice in different parts of the same cave."

Regierungsrath Franz Kraus, in 1895, wrote a short essay on glacières in *Höhlenkunde*. He seems to have seen but few glacières himself, and considers the scientific side of the question by no means solved as yet. He says: "The last word will not be spoken by the geographers and the Alpine climbers * * * but by the physicists, in whose field both questions really belong. Only then, when the physical circumstances of the formation of the ice in glacières have been so thoroughly understood, that under the same circumstances it may be possible to build artificial glacières, only then could one say: the glacière question is definitely settled. The best proof is always experiment."

He lays down several dicta which he says are

universally recognized, among which is this: "2. The ice formations in the débris heaps of basaltic mountains are summer ice formations. The evaporation of the infiltration water is recognized on all sides as the cause of this ice." I differ in opinion from Herr Kraus about this matter, and think that, on the contrary, every proof shows that the ice of basaltic taluses is not a summer formation and is not due to evaporation.

Herr Kraus also says: "The *Eishöhlen* resemble so little the *Windröhren*, that for these a proper name is quite correct. Just as one cannot draw a sharp line between *Einstürzschlünden* and *Einstürzdolinen*, so one cannot draw a sharp line between *eishöhlen* and *windröhren*. A stagnation of cave air does not exist, and no cave student would pretend to say it existed. The circulation of air may in certain caves take place almost entirely through the mouth and it then depends largely on the shape of the latter; in other caves are crevices and erosion holes, which allow a circulation of air. Again in other caves air may come through the floor into the cave, as is proved by certain places always remaining free from ice."

He also says: "The formation of dripstone is also diminished about thick roofs, when the cracks are too broad to permit a slow dripping process. In caves with sufficient air movements, that is ventilation, the dripstone formation takes place faster than in those in which the air is only slowly renewed. Also in such caves, in which the air is strongly filled with moisture, the dripstone forma-

tion process is materially hindered. Therefore in water caves and in *eishöhlen* one finds only rarely dripstone formations, and these mainly of poor appearance. But in all cases the carbonic acid of the infiltration water plays an important part."

In 1896, a Western newspaper published the following explanation about the presence of ice in the cave at Elkinsville, Indiana; and it shows how the idea—long since exploded—of the ice being due to chemical causes, serenely bobs up on the discovery of a new cave: "Some have advanced the theory that the air is forced through under passages of the earth with such pressure as to make the strange formation; some have attributed the cause to an underlying bed of alkali, whose chemical change to a gaseous form has produced the phenomenon. Others have thought that the interior heat of the earth, acting upon the iron pyrites, or fool's gold, which largely abounds in this country, is the true source of this unparalleled discovery. Still others think that the sudden expansion of the carbonic acid gas given off by the heated limestone, which is also common in this country, could have easily produced the ice. But thus far the theories are nothing more than speculation, and further than the fact that the ice cave exists, and is, indeed, a remarkable phenomenon, none has been able to further determine."

In 1896, Dr. A. Cvijic wrote that the cold air of winter is the source of cold in the glacières of Servia. The

mountains have so little water that the shepherds constantly take the ice out in summer for their own use.

In 1897, numerous newspapers, among others, the *Philadelphia Press* of August 1st, romanced as follows about the cave at Decorah: "In the summer its temperature is far below freezing. * * * From some unknown source in the impenetrable rear of the cave comes a blast of cold air as chill as from the Arctic region. In the winter the temperature of the cave is like summer. * * * We followed the winding passage in and out for more than 1000 feet. * * * I took out the thermometer and laid it upon the floor of the cavern for three minutes. When I took it up again I found that the mercury had fallen to 5 degrees below zero."

"What is it that causes this phenomenon? Scientific men are said to have visited the cave within the last day or two who have declared that it had in some manner a subterranean connection with the polar regions, and that the cold air from the North coming in contact with the warm moist atmosphere from outside converted the vapor into water on the walls of the cavern where it straightway congealed. * * * It seems to me possible after thinking the matter over carefully, that in some mysterious manner the same influences that work the changes in climate in the Arctic and Antarctic regions are operating in this cave. It is a well-known fact that in the regions referred to the seasons are the reverse of what they are here."

Mr. W. S. Auchincloss writes in 1897: "We also notice the working of the same principle during summer days. The hottest part does not occur at the noon hour—when the sun is on the meridian—but several hours later in the afternoon. In this case the accessions of heat arrive more rapidly than radiation is able to carry off. Radiation, however, keeps on apace, and, at last attaining the mastery, temperature falls. Ice caves furnish another example of the gradual procession in the seasons."

Mr. Alois F. Kovarik writes about Decorah in 1898 that "the length of duration of the ice in the cave during the spring and summer depends upon the quantity of cold stored up in the walls and this again upon the coldness and the length of coldness of the previous winter. If the winter be severe and long, the walls will store up a great supply of cold for the gradual dissipation in the spring and summer and consequently the phenomenon of the ice in the ice chambers will last longer. Last winter, with an exception of the fore part of December, was quite mild. As a result, the ice began to disappear with the latter part of June, and totally disappeared by the end of July. * * * The time of the lowest temperature in the cave depends upon how soon the cold spells of the winter begin; for the sooner the walls begin to freeze to a greater depth, the sooner have they stored up the greatest amount of cold. * * * February 28th, 1898, when the walls contained the greatest amount of cold, there was no ice in the cave, for the reason that no water

made appearance. Could water have appeared, no doubt a great amount of ice would have formed; but as the conditions are, the water has to come from the ground outside, and this being frozen at the time, water could not in any natural way appear. If in early spring, sufficiently warm days should come to melt the snow and open the ground, the water not taken up by the ground would flow and seep through crevices into the cave and ice consequently would appear early. Somewhat such conditions prevailed this year, for warm days appeared quite early in the spring. If *per contra* the ground does not open until in April, as was the case in 1895 and 1896, the appearance of the ice is consequently delayed. * * * Naturally this opening [the entrance] was small, but to give easier entrance, it was enlarged to its present size. * * * If the entrance had been left a small opening, as it naturally was, it is my belief that the temperature of the interior of the cave would be lower in summer than it is, and the ice would not disappear as soon as it does."

Mr. Robert Butler, of San José, Cal., investigated the question of cold air draughts coming from the glacière cave and from the freezing shaft he examined in Montana. He wrote to me, in 1898, that he found that one notices or imagines to notice a draught of air, especially on hot days. Rapidly walking into the cave from the hot air without to the rapidly cooling air within produces the same nervous sensations as though one were to remain stationary and the air were to pass by from the warm to the

colder portions. A distance of twelve meters finds a difference in temperature of fifteen degrees Centigrade. Twelve meters can be walked quickly, so quickly that the nerves cannot become accustomed gradually to the change of temperature. The rapidly cooling air does actually produce the sensation of cool air passing by one's face. It produces somewhat the same sensation as the evaporation of ether on the surface of the body. Mr. Butler satisfied himself that as far as he had observed all the seemingly peculiar conditions and places where the ice has been found do not indicate any other causes when carefully investigated than those of the seasons of the year, and that the ice was formed by no other cause than the natural cold of winter.

Professor Cranmer, in 1899, added some important contributions to our knowledge of freezing caverns. All his work goes to prove the winter's cold theory, but he has brought out some new details. He found warm and cold periods in the Tablerloch during the winter months. The coldest air sank to the bottom and the air in the cave stratified itself according to its specific gravity and its temperature. During a cold period, the outside air sank into the cave only to the air stratum, whose temperature, from the preceding warm period, was as much higher as that of the outer air, as this had become warmer in sinking to that stratum. The air which enters falls down the slope and displaces an equal volume of air which streams out under the roof.

Water will sometimes drip through a crack in winter until that crack freezes up, when the water may then find some other crack to drip through; at this second place a stalagmite may then grow, while at the first place the stalagmite may stop growing and even begin to diminish from evaporation.

Ice begins to form, whenever water gets into a cave, if the cave temperature is below 0°; ice begins to melt as soon as the temperature is over 0°.

Professor Cranmer found that occasionally small quantities of ice form in caves in the summer months: this was in mountain caves, where there was snow on the mountains and the temperature of the nights at least, had sunk below freezing point: in fact when the conditions were those of the winter months.

PART V.

LIST OF AUTHORS.

LIST OF AUTHORS.[75]

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[75] This list of authors includes all the authorities which I have personally consulted. Several papers, such as Dr. Schwalbe's "*Uebersichtliche Zusammenstellung Literarischer Notizen ueber Eishöhlen*" and the works of Dr. Listoff, I have been unable to find in any library.

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